

# **PaSim User's guide**

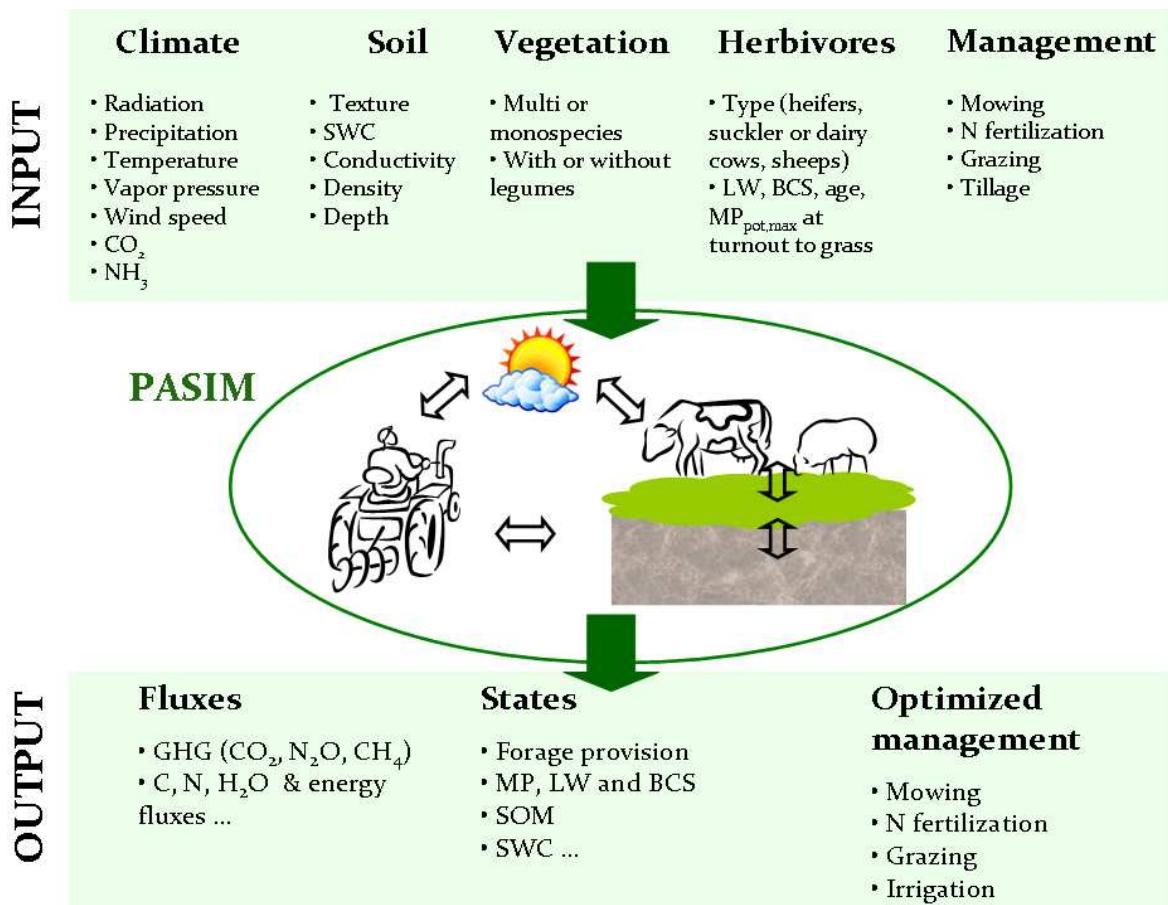
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**Figure 1: Description of the PaSim model**

# Introduction

PaSim (**Riedo et al. 1998**, <https://www1.clermont.inra.fr/urep/modeles/pasim.htm>)<sup>1</sup> is a process-based grassland ecosystem model based on the Hurley Pasture Model (**Thornley 1998**) whose main aim is to simulate climate change impacts on grassland services, and feedbacks associated with GHG emissions to the atmosphere. It was first programmed in ACSL (Advanced Continuous Simulation Language, [http://en.wikipedia.org/wiki/Advanced\\_Continuous\\_Simulation\\_Language](http://en.wikipedia.org/wiki/Advanced_Continuous_Simulation_Language)) and developed at the Research Station Agroscope (Switzerland, Reckenholz) from 1997 to 2002. Since then, it is developed at the Grassland Ecosystem Research Unit of the French National Institute for Agricultural Research (France, Clermont-Ferrand, <https://www1.clermont.inra.fr/urep/>). The software is now written in Fortran 90 language (language translation by A. Cozig) and contains about 60 000 lines. It is composed of submodels for plants, animals, microclimate, soil biology, soil physics and management. The 5.3 version of the model is about to be submitted at the APP (French agency for software protection).

This manual aims at describing the basic structure and use of PaSim for single-year, multi-year and steady state simulations.

## 1 PaSim presentation

### 1.1 General description

Grassland processes are simulated on a time step of a 1/50<sup>th</sup> of a day in order to have detailed sub-daily dynamics and ensure energy budgets stability. Simulations consider a soil-vegetation-animal-atmosphere system (with state variables expressed per m<sup>2</sup>) and run over one or several years. Animal processes are simulated at pasture but not in the barn.

As with other advanced biogeochemical models, PaSim simulates water, carbon (C) and nitrogen (N) cycles. Photosynthetic C is allocated dynamically to root and shoot compartments and can be lost from the modelled system through ecosystem respiration, animal milking, and enteric CH<sub>4</sub> emissions. Vegetation is assumed to consist of one root and of three shoot compartments (laminae, sheaths and stems, ears), each of which is further divided into four age classes. Biological N<sub>2</sub> fixation is modelled according to **Schwinning and Parsons (1996)**, when assuming a constant legume fraction. Vegetation is parameterized for a set of key functional traits such as the maximum specific leaf area, the light-saturated leaf photosynthetic rate in standard conditions, the fraction of fibres in ingested shoot compartments and the fraction of digestible fibres in total ingested fibres. Accumulated aboveground biomass can be utilized by cutting and grazing, or enters a litter pool. The N cycle considers three types of N inputs to the soil via atmospheric N deposition, fertilizer N addition, symbiotic N<sub>2</sub> fixation by legumes, and animal faeces and urine.

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<sup>1</sup> PaSim littérature: Riedo et al. (1998, 1999, 2000, 2001, 2002), Schmid et al. (2001), Vuichard, (2005), Vuichard et al. (2007a,b), Calanca et al. (2007), Graux, (2011), Graux et al., (2011a,b), Lardy et al. (2011)



The inorganic soil N available for root uptake may be reduced through immobilization, leaching, ammonia volatilization and nitrification/denitrification, the latter processes leading to N<sub>2</sub>O emissions to the atmosphere. Management includes mineral and/or organic (e.g. solid manure, slurry) N fertilization, mowing and grazing and can either be set by the user or optimized by the model.

## 1.2 Recent improvements

PaSim was improved by **Schmid et al. (2001)** and **Riedo et al. (2002)** to simulate, respectively, N<sub>2</sub>O production and emission and the exchange of ammonia with the atmosphere.

**Vuichard et al. (2007a)** further developed PaSim to simulate animal herbage selection at pasture and associated enteric methane emissions. They also improved the simulation of herbage biomass dynamics by accounting for the limitations induced by high leaf area index, soil water deficits and aging of leaves. They added a two-step procedure which allowed determining the optimal stocking rate and fractional coverage of grazing at the forage system scale.

Since then, **Graux (2011)** performed the model for:

- Vegetation:  
i) Water stress parameterization to be less influent, ii) plant reserve addition, iii) parameterization for sown (*Festuca arundinacea* L. and *Lolium perenne* L.) and permanent grasslands.
- Soil:  
i) N<sub>2</sub>O diffusion calculation, ii) surface temperature simulation (a litter layer at top soil was included), iii) SOM equilibrium (a new algebraic method was developed, **Lardy et al., 2011**).
- Grazing animals:  
In order to improve the accuracy of animal performance simulation during grazing, we developed a new version of the animal module of PaSim. In this version, three animal classes can be simulated (**Graux et al., 2011**): suckler cows (and their calves), dairy cows and heifers (only one class of cattle can be simulated within the same simulation).  
(i) With suckler cows, animal growth and production are described following the SEBIEN model (see **Jouven et al. 2008**) except for selective intake of sward structural components.  
(ii) With heifers and with dairy cows, a new mechanistic model consistent with SEBIEN was developed to simulate intake, growth and (with dairy cows) lactation.  
(iii) Simulation of enteric CH<sub>4</sub> emissions is now based on **Vermorel et al. (2008)**.  
(iv) Temperature effects on forage digestibility and ingestibility are simulated.  
(v) A new module was developed to simulate dairy cows' supplementation by roughage and/or concentrate feed.
- Management:  
i) Acceleration of SOM mineralization due to tillage for sown grasslands,  
ii) irrigation and N fertilization automatic management (based on water stress and nitrogen nutrition indexes).



PaSim has also been improved (in collaboration with IRSN, the French *Institut de radioprotection et de sûreté nucléaire*) to simulate  $^{14}\text{C}$  and  $^{13}\text{C}$  cycles (E. Duclos, ISIMA training period) to assess radioactive traces in milk and meat products.

### 1.3 Model evaluation

All previous improvements have been evaluated against experimental data. In particular, PaSim was tested against experimental data at three European sites performing  $\text{CO}_2$ ,  $\text{N}_2\text{O}$  and  $\text{CH}_4$  flux measurements (**Vuichard et al. 2007a**).

PaSim has been used intensively in a set of European (CarboEurope IP, NitroEurope IP, CARBO-Extreme) and French (CLIMATOR, VALIDATE) research projects<sup>2</sup>.

The model needs to be assessed as regards  $\text{CH}_4$  emissions for suckler and dairy cows, either supplemented or not.

### 1.4 Validity domain

Based on previous studies (**Riedo et al. 1998**, **Vuichard et al. 2007a,b** and unpublished data), the validity domain of the model corresponds to:

- European soil-climate conditions
- Permanent and sown grasslands
- Suckling and dairy pasture-based seasonal calving systems
- French cattle breeds (Prim'Holstein, Montbéliarde, Normande, Charolais, Salers)

### 1.5 Modelling limitations

Despite its continuous development and improvement, some limitations remain:

- Vegetation:

PaSim representation of vegetation uses a compartment based approach, neglecting (i) the spatial heterogeneity in paddocks (diversity of plant populations, of species and of cultivars)

(ii) almost fully the functional role of plant diversity

- Soil:

PaSim representation of soil uses does not account for:

(i) soil-atmosphere  $\text{CH}_4$  exchange

(ii) the heterogeneous nature of the vertical distribution of C in the soil profile

(iii) soil organic matter pools are (usually) initialized to values closed to their steady state equilibrium values after a spin-up run

PaSim still fails to faithfully reproduce timing, duration and magnitude of peak emissions triggered by the application of mineral and organic fertilizers and by rain events (**Calanca et al. 2007**).

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<sup>2</sup> aiming at understanding the C and N cycles, carbon sequestration, greenhouse gases emissions (GHG) and the effects of climate variability and climate change on grasslands.



- Cattle:

PaSim representation of cattle does not consider:

- (i) differences in individual energy needs and reproduction cycle
- (ii) diet chemical composition and animal breed for enteric CH<sub>4</sub>
- (iii) the herbage digestibility dependance of factors used to convert metabolizable energy intake into CH<sub>4</sub> production (conversion factors are assumed constants for suckler cows and heifers)

- Environment

The simulation of grassland ecosystems does not allow simulating:

- (i) the possible effects of diseases, pests and weeds on grassland production
- (ii) tropical soil-climate conditions

## 1.6 Model strengths

PaSim simulates thoroughly and mechanistically:

- (i) Energy, C, N and water balance of grassland ecosystems
- (ii) Forage provisioning
- (iii) Performance of grazing ruminants
- (iv) Potential to sequester C in grassland soils
- (v) GHG emissions at pasture (including ecosystem respiration, N<sub>2</sub>O and enteric CH<sub>4</sub>)
- (vi) Climatic effects on grassland ecosystems functioning, such as heat and water balance effects on the vegetation and heat stress effects on livestock production

It has been already involved in long-term simulations to assess climate change impacts. PaSim is therefore a useful research tool to study climate change impacts on livestock systems and to investigate adaptation options.

## 1.7 Work in progress

PaSim is currently developed to:

- Vegetation:

Simulate a legume dynamics and the dynamics of community scale plant functional traits in response to climate and to agricultural practices.

- Management:

Improve the two-step procedure which allows determining the optimal stocking rate and fractional coverage of grazing at the forage system scale, so that it can account for past climate (instead of future climate) and for the role of conserved forage in ensuring the security of the feeding systems by disposing of sufficient reserves to meet production hazards.

- Climate:

Simulate tropical grasslands in the framework of the ANR Projet « EPAD » (2010-2013, <http://epad.cirad.fr/>)

## Hourly Data

VARIABLE	DESCRIPTION	UNIT	NECESSARY MODIFICATIONS
<b>Pa</b>	Precipitations	mm.d <sup>-1</sup>	PASIM needs <b>daily weather data at each hourly time step</b> . If precipitations are in mm.h <sup>-1</sup> , multiply by 24.
<b>Ta</b>	Average air temperature	K	If temperature is in Celsius degrees, add 273,15.
<b>U</b>	Wind speed	m.s <sup>-1</sup>	-
<b>IATMtot</b>	Radiation	W.m <sup>-2</sup>	If radiation is in J cm <sup>-2</sup> , divide by 0.36
<b>Ea</b>	Water vapour pressure	kPa	If Relative humidity (RH), use Bolton (1980):  $Ea=0,6112 \cdot \exp((17,67 \cdot Ta)/(Ta+243,5)) \cdot RH/100$ , Where Ta is in °C
<b>CO2</b>	CO <sub>2</sub> concentration	atmospheric	ppm
<b>NH3</b>	NH <sub>3</sub> concentration	atmospheric	ppm
			2 could be set as default value

## Daily Data

VARIABLE	DESCRIPTION	UNIT	NECESSARY MODIFICATIONS
<b>Tamax</b>	Daily max air temperature	°C	-
<b>Tamin</b>	Daily min air temperature	°C	-
<b>Pa</b>	Daily Precipitations	mm.d <sup>-1</sup>	-
<b>IATMtot</b>	Radiation	J cm <sup>-2</sup>	-
<b>RH</b>	Relative Humidity	%	-
<b>U</b>	Daily mean Wind speed	m.s <sup>-1</sup>	-
<b>CO2</b>	Daily mean CO <sub>2</sub> atmospheric concentration	ppm	-
<b>NH3</b>	Daily mean NH <sub>3</sub> atmospheric concentration	ppm	2 could be set as default value

Table 1: Description of A) hourly or B) daily climate variables needed to run PaSim

## 2 PaSim simulations

### 2.1 How to fill in files

#### 2.1.1 Input files

Input data required to run PaSim are split into 5 files for:

- Climate
- Management
- Site specific conditions (latitude, altitude, soil properties etc.)
- Initial conditions for plant, soil and animals
- Run properties (options, output variable list, simulation length, etc.)

See the usual tree structure of PaSim in **Annexe 1**.

As PaSim is developed in Fortran language, input data must not contain coma. Decimal separator must be point. To separate columns you can use either space or tabulation.

#### 2.1.1.1 Weather data files

##### 2.1.1.1.1 Hourly meteorological data

PaSim needs one file for each meteorological variable (**Tab. 1**). Each of these files must have 4 columns:

- Year (number 1 for the first year of simulation)
- Day (Julian day from 1 to 365, PaSim do not consider bissextile year)
- Hour (1 to 24)
- Climate variable of the file

##### 2.1.1.1.2 Daily meteorological data

PaSim offers the possibility to use daily meteorological data. However, note that using daily meteorological data instead of hourly meteorological data will reduce result precision.

To use daily meteorological data you will have to set the FLAG\_READ\_METEO flag to 1 into the “site.pasim” file. All meteorological (**Tab. 1**) data need to be aggregated into one file in the following order:

- Year
- Day
- Daily max temperature
- Daily min temperature
- Daily precipitation
- Daily Radiation
- Relative humidity
- Daily mean Wind speed
- Daily mean CO<sub>2</sub> concentration
- Daily mean NH<sub>3</sub> atmospheric concentration

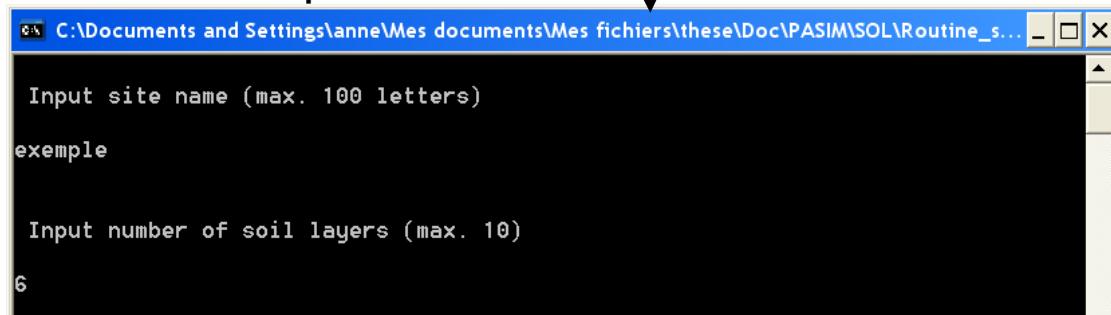
VARIABLE	DESCRIPTION	UNIT
Tcut	Date of a cutting event	Julian day
Tfert	Date of a fertilization event	Julian day
Nfertamm	Amount of N-ammonium for each application of mineral fertilizer	kg N m <sup>-2</sup>
Nfertnit	Amount of N-nitrates for each application of mineral fertilizer	kg N m <sup>-2</sup>
Nanimal	Stocking rate	animal/m <sup>2</sup>
Tanimal	Start of the grazing period	Julian day
Danimal	Length of the grazing period	day
Nliqmanure	Amount of N for each application of liquid manure	kg N m <sup>-2</sup>
Nslurry	Amount of N for each application of slurry	kg N m <sup>-2</sup>
Nsolmanure	Amount of N for each application of solid manure	kg N m <sup>-2</sup>
LWYcows	Initial average liveweight of young/primiparous cows at the beginning of the considered grazing period	kg animal <sup>-1</sup>
LWMcows	Initial average live weight of mature/multiparous cows at the beginning of the considered grazing period	kg animal <sup>-1</sup>
BCSYcows	Initial average body condition score of young/primiparous cows at the beginning of the considered grazing period	-
BCSMcows	Initial average body condition score of mature/multiparous cows at the beginning of the considered grazing period	-
LWcalves	Initial average liveweight of calves at the beginning of the considered grazing period	kg animal <sup>-1</sup>
AGE_cow_P	Age for primiparous cows at the start of the considered grazing period	Month
AGE_cow_M	Age for multiparous cows at the start of the considered grazing period	Month
Forage quantity	Forage quantity supply to supplement cows at pasture	kg DM animal <sup>-1</sup> d <sup>-1</sup>

Table 2: Description of management variables needed in PaSim input

- **Soil-input-exemple.txt**

z [m]	fclay [-]	fsilt [-]	fsand [-]	rhob [kg m <sup>-3</sup> ]	Qsat [m <sup>3</sup> m <sup>-3</sup> ]	[m <sup>3</sup> m <sup>-3</sup> ]
0.02	0.54	0.32	0.13	591	0.53	
0.05	0.54	0.32	0.13	591	0.53	
0.1	0.54	0.32	0.13	742	0.53	
0.3	0.56	0.32	0.12	874	0.46	
0.51	0.57	0.33	0.1	1205	0.46	
0.7	0.56	0.34	0.1	1205	0.46	

- **estimate-soil-parameters.exe**



**3. Test-layers-exemple.txt**

layer	z	zT
1	0.020	0.000
2	0.050	0.040
3	0.100	0.060
4	0.300	0.140
5	0.510	0.460
6	0.700	0.560

layer	z [m]	Psie [mm]	b [-]	ksat [mm/d]	Qsat [m <sup>3</sup> /m <sup>3</sup> ]	Qfc [m <sup>3</sup> /m <sup>3</sup> ]	Qpwp [m <sup>3</sup> /m <sup>3</sup> ]
1	0.020	-589.126	13.908	24.995	0.530	0.468	0.355
2	0.050	-589.126	13.908	24.995	0.530	0.468	0.355
3	0.100	-589.126	13.908	24.995	0.530	0.468	0.355
4	0.300	-631.338	14.541	21.773	0.460	0.410	0.315
5	0.510	-665.724	15.010	19.583	0.460	0.413	0.320
6	0.700	-654.967	14.794	20.220	0.460	0.412	0.318

Figure 2: Description of soil routine utilization

*NB: When using daily meteorological data, you have to repeat 7 times the path of the daily meteorological data file in the “name\_files\_input” file.*

*For instance:*

```
./Input/condition/oens.site_spe.par
./Input/condition/oens.init_cond.par
./Input/condition/oens.management.dat
./Input/meteo/oens.Daily_meteo.dat
./Input/meteo/oens.Daily_meteo.dat
./Input/meteo/oens.Daily_meteo.dat
./Input/meteo/oens.Daily_meteo.dat
./Input/meteo/oens.Daily_meteo.dat
./Input/meteo/oens.Daily_meteo.dat
./Input/meteo/oens.Daily_meteo.dat
```

Just the daily temperature and radiation are interpolated into hourly weather data (other variables remain constant during the day). Their interpolation is based on equations from “Grassland dynamics, an ecosystem simulation model” (Thornley, 1998, p.146-150).

### 2.1.1.2 Management file

For each type of agricultural practice (mowing, grazing, N fertilization), PaSim user can fulfil up to 10 events per year. When less than 10 values of the date of an event (e.g. cutting event) are available, put a number greater than 366 (e.g. 500).

Data must be fulfilled in a specific order (**Tab. 2**). The first line of the management file is just for user, it is usually a simple remind of the different variables. For example, the first line can be:

tcut / tfert / Nfertamm / Nfertnit / nanimal / tanimal / danimal / Nliqmanure / Nslurry / Nsolmanure/ LW of young cows / LW of mature cows / BCS of young cows / BCS of mature cows / Initial calf LW (at the beginning of grazing period) / Initial age of primiparous cows / Initial age of multiparous cows / Forage quantity

Each of the next lines represent one year of management and must contain 18 times 10 values of variables (See **Annexe 2** for example of management file).

Model inputs for animals are, for both dairy and suckling systems, (i) the grazing periods (maximum 10) and the corresponding stocking rates, (ii) the calving date, (iii) the average maximum milk production (at peak of lactation), (iv) the initial average liveweight and body condition score of cows at each new grazing period<sup>3</sup>.

The old animal module (Type of animal=3) only uses the 10 first management variables (100 columns) but the 180 columns still need to be present in the file.

*NB: If you have no information about inorganic fertilizer, note you can consider that it is a 50:50 mixture of ammonium nitrate*

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<sup>3</sup> Whenever the stocking rate is changing, PaSim considers that a new grazing period is beginning

VARIABLE	UNIT	HELP	ADVISED VALUE
Description	-		
Latitude N (exemple: 55° 52' 20")	rad	[-π/2: π/2] Exemple: (55 °+(52'/60) (20"/3600))*2 π/360	-
Time of the highest position of the sun	h:min	[0:24]	12.12
Slope (rad)	rad	[-π: π] or [0:2 π]	0.0
Aspect (rad)	rad	[-π: π] or [0:2 π]	0.0
Height above sea level	m a.s.l.		
Micrometric reference height above soil surface	m a.s.l		2.0
NH <sub>3</sub> reference height above soil surface	m a.s.l		2.0
Number of soil layers	-	Soil will be highly better simulated with 6 soil layers	6.0
Cumulated depth of soil layers	mm	First layer must be 20 mm	
Cumulated depth of lower soil boundary layer (mm)	mm	Must be larger than previous soil layer	
Maximal canopy height	m		
Canopy height parameter (leaf area index for which canopy is half the maximum canopy height)	m <sup>2</sup> laminae m <sup>-2</sup>	Does not change	4.0
Clover fraction	kg kg <sup>-1</sup>		
Relative root dry matter in different soil layers	- (fraction)	Sum of all layers has to be 1	
Soil depth below which there is neither plant N uptake, nor soil texture effect of active SOM decomposition	m		0.2
Bulk density of each soil layer	kg L <sup>-1</sup>	All the same or increasing values	
Sand fraction of texture	-		
Clay fraction of texture	-		
Silt fraction of texture	-		
Saturated soil water content	m <sup>3</sup> m <sup>-3</sup>	(could be estimated thanks to the following formula 1 - dentity/2.65)	
Saturated soil water content of lower boundary layer	m <sup>3</sup> m <sup>-3</sup>	Same as last layer	
Air entry potential*	mm	Use soil routine	
Air entry potential of lower soil boundary layer*	mm	Same as last layer	
Parameter b in psi*	-	Use soil routine	
Parameter b of lower soil boundary layer*	-	Same as last layer	
Saturated hydraulic conductivity*	mm d <sup>-1</sup>	Use soil routine	
Saturated hydraulic conductivity of lower soil boundary layer*	mm d <sup>-1</sup>	<b>NOT USED ANYMORE</b>	
Parameter for the determination of the field capacity	-	<b>NOT USED ANYMORE</b>	
Field capacity*	m <sup>3</sup> m <sup>-3</sup>	Use soil routine	0.01
Permanent wilting point*	m <sup>3</sup> m <sup>-3</sup>	Use soil routine	
Soil pH	-		7.0
Parameter a for Freundlich equation for soil NH <sub>4</sub> <sup>+</sup> partitioning	-	Does not change	1.076
Parameter b for Freundlich equation for soil NH <sub>4</sub> <sup>+</sup> partitioning	-	Does not change	0.66

a.s.l: above sea level

\* calculated by of the soil routine of Pierluigi Calanca

Table 3: Description of site specific variables needed in PaSim input

### 2.1.1.3 Site specific file

This file (**Tab. 3 and Figure 3**) describes the site characteristics as well as the vegetation and soil properties. However, vegetation and soil properties for initialization and management will be defined in the initial condition file. Also some of these parameters can be modified into the run file. An example of a site specific file is given below.

To parameterize the soil, a soil routine (**Figure 2**) has been developed by Pierluigi Calanca (Research Scientist at Agroscope Reckenholz-Tänikon Research Station ART, Zurich, Switzerland). This routine needs the number, the depth, the texture and the water saturation of each soil layer as input (Cf. soil-input-exemple.txt). Then the PaSim user has to run estimate-soil-parameters.exe and the routine creates 2 output files (see Figure 2):

- a “test layer” file
- a “soil output file”

This routine as also been implemented into the interface (The soil tab, p. 42)

oens.site_spe.par	
0	Description
0.825	Latitude N (rad)
12.3	Time of the highest position of the sun (h:min)
0	Slope (rad)
0	Aspect (rad)
450	Height above sea level(m)
1.5	Micromet reference height above soil surface (mm)
1.5	NH3 reference height above soil surface (m)
6	Number of soil layers (max=6)
20 100 200 400 700 1000	Depth of soil layers (mm)
1500	Depth of lower soil boundary layer (mm).
0.4	Maximal canopy height (m)
5	Canopy height parameter
0.25	Clover fraction (kg/kg)
0.306 0.303 0.251 0.125 0.014 0.001	Relative root dry matter in different soil layers (-)
0.25	Main rooting depth (m)
1.15 1.15 1.15 1.15 1.15 1.15	Bulk density (kg/l)
0.24 0.24 0.24 0.24 0.24 0.24	Volume fraction of quartz in soil (m <sup>3</sup> /m <sup>3</sup> )
0.43 0.43 0.43 0.43 0.43 0.43	Clay fraction of texture (-)
0.33 0.33 0.33 0.33 0.33 0.33	Silt fraction of texture (-)
0.56 0.56 0.56 0.56 0.56 0.56	Saturated soil water content (m <sup>3</sup> /m <sup>3</sup> )
0.56	Saturated soil water content of lower soil boundary layer (m <sup>3</sup> /m <sup>3</sup> )
-410 -410 -410 -410 -410 -410	Air entry potential (mm)
-410	Air entry potential of lower soil boundary layer (mm)
11.15 11.15 11.15 11.5 11.5 11.5	Parameter b in psi (-)
11.5	Parameter b of lower soil boundary layer (-)
51.5 51.5 51.5 51.5 51.5 51.5	Saturated hydraulic conductivity (mm/d)
51.5	Saturated hydraulic conductivity of lower soil boundary layer (mm/d)
0.01	Parameter for the determination of the field capacity
0.464 0.464 0.464 0.464 0.464 0.464	Field capacity
0.329 0.329 0.329 0.329 0.329 0.329	Permanent wilting point
6.5	Soil pH
1.076 1.076 1.076 1.076 1.076 1.076	Parameter a for soil NH4+ partitioning
0.66 0.66 0.66 0.66 0.66 0.66	Parameter b for soil NH4+ partitioning

**Figure 3: Example of a site specific conditions file**

VARIABLE	UNIT	HELP	ADVISED VALUE
Initial condition of shoot dry matter	kg DM m <sup>-2</sup>		
Shoot dry matter after cutting	kg DM m <sup>-2</sup>	10 values	
Initial condition of root dry matter	kg DM m <sup>-2</sup>		
Initial condition of LAI	m <sup>2</sup> laminae m <sup>-2</sup>		1
LAI after cutting	m <sup>2</sup> laminae m <sup>-2</sup>	10 values	
Initial cond. for plant C substrate concentration	kg C kg DM <sup>-1</sup>	Prefer default value	0.04
Initial cond. for plant N substrate concentration	kg N kg DM <sup>-1</sup>	Prefer default value	0.002
Initial cond. for N conc. of structural plant dry matter	kg N kg DM <sup>-1</sup>	Prefer default value	0.022
Initial cond. for C in structural dead plant material	kg C m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for C in metabolic dead plant material	kg C m <sup>-2</sup>	Prefer default value	0.814
Initial cond. for C in active soil organic matter	kg C m <sup>-2</sup>	Prefer default value	0.052
Initial cond. for C in slow soil organic matter	kg C m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for C in passive soil organic matter	kg C m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for N in metabolic dead plant material	kg N m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for N in active soil organic matter	kg N m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for N in slow soil organic matter	kg N m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for N in passive soil organic matter	kg N m <sup>-2</sup>	Prefer default value	0.001
Initial cond. for soil ammonium	kg N m <sup>-2</sup>	Prefer default value	0.00025
Initial cond. soil nitrate	kg N m <sup>-2</sup>	Prefer default value	0.00035
Initial condition for soil water content	m <sup>3</sup> m <sup>-3</sup>	Should not be higher than saturated value	
Capillary rise from lower boundary layer, yes (1.0) or no (0.0)	-		
Water content of lower soil boundary layer in spring	m <sup>3</sup> m <sup>-3</sup>	Should not be higher than saturated value	
Water content of lower soil boundary layer in autumn	m <sup>3</sup> m <sup>-3</sup>	Should not be higher than saturated value	
Average temperature of lower soil boundary layer	K	Is now estimated by the model. So use default value	283.8
Amplitude of temperature of lower soil boundary layer	K	Is now estimated by the model. So use default value	3.6
Phase of temperature of lower soil boundary layer	Rad		
NH <sub>4</sub> <sup>+</sup> deposition other than gaseous NH3	kg N m <sup>-2</sup> d <sup>-1</sup>	Prefer default value	0.00000145
NO <sub>3</sub> <sup>-</sup> deposition	kg N m <sup>-2</sup> d <sup>-1</sup>	Prefer default value	0.00000151
Dates of cutting and grazing calc. by model (1) or on input (0)	-	0	0
Potential eating rate of lactating cows	kg DM animal <sup>-1</sup>	only used by old module	15
Weight of lactating cows	Kg	only used by old module	650
Type of animal	-	1 = dairy cows; 2 = suckler cows 3 = old module version (dairy cows ) 4 = dairy heifers 5 = suckler heifers 6 = sheep with old module Useless for old module version	
Calving date for dairy or suckler livestock system	d	Useless for old module version	
Suckling period for suckler livestock system	d	Useless for old module version	
Age of the calves exit for suckler livestock systems	d	Useless for old module version	
Proportion of young suckler cows (3 or 4 years old) or primiparous dairy cows in the cattle	-	Useless for old module version	
Calf birth Weight for suckler livestock systems	kg	Useless for old module version	45
Milk production at peak*	kg animal <sup>-1</sup> d <sup>-1</sup>	Useless for old module version	8 10 for suckling systems 28 34 for dairy systems
Quantity of concentrate provided per kg of milk	kg DM (kg of milk) <sup>-1</sup>	Useless for old module version	0.125
Concentrate energy value	UF kg <sup>-1</sup>	Useless for old module version	
Forage energy value	UF kg <sup>-1</sup>	Useless for old module version	
Forage fill value	UE kg <sup>-1</sup>	Useless for old module version	
N fraction in the forage	kg N kg <sup>-1</sup>	Useless for old module version	0.120
N fraction in the concentrate	kg N kg <sup>-1</sup>	Useless for old module version	0.120
Initial cow liveweight of for automatic management*	kg	Only used for automatic management	600 650
Initial cow body condition score for automatic management *	-	Only used for automatic management	3 3
Initial cow age for automatic management *	months	Only used for automatic management	32 44

\*(first: young/primiparous, second: mature/multiparous)

Table 4: Description of initial conditions variables needed in PaSim input

## 2.1.1.4 Initial conditions file

Initial condition file (**Tab. 4 and Figure 4**) describes initial conditions for plant, soil and grazing animals. It contains also information about vegetation management. An example of this file is given below.

*NB: Initial soil organic matter (SOM) pool values could be either given by PaSim user if known (but it is rarely the case, and when total SOM is known, it is difficult to share it between the 10 SOM pools of PASIM), or obtained by running the model to reach SOM equilibrium (See 6.3 for more explanations).*

oens.init\_cond - Bloc-notes

Fichier	Edition	Format	Affichage	?
---------	---------	--------	-----------	---

```

0.15 Initial condition of shoot dry matter(kg/m**2)
0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 Shoot dry matter after cutting (kg/m**2)
0.58 Initial condition of root dry matter (kg/m**2)
1 Initial condition of LAI (m**2/m**2)
0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4 0.4 LAI after cutting
0.04 Initial cond. for plant C substrate concentration (kg C/kg)
0.002 Initial cond. for plant N substrate concentration (kg N/kg)
0.022 Initial cond. for N conc. of struct. plant dry matter (kg N/kg)
0.814 Initial cond. for C in struct. dead plant material (kg C/m**2)
0.052 Initial cond. for C in metabolic dead plant material (kg C/m**2)
0.001 Initial cond. for C in active soil organic matter (kg C/m**2)
0.001 Initial cond. for C in slow soil organic matter(kg C/m**2)
0.001 Initial cond. for C in passive soil organic matter (kg C/m**2)
0.0043 Initial cond. for N in metabolic dead plant material (kg N/m**2)
0.001 Initial cond. for N in active soil organic matter (kg N/m**2)
0.001 Initial cond. for N in slow soil organic matter (kg N/m**2)
0.001 Initial cond. for N in passiv soil organic matter (kg N/m**2)
0.0004 Initial cond. for soil ammonium (kg N/m**2)
0.0004 Initial cond. for soil nitrate (kg N/m**2)
0.35 0.35 0.35 0.35 0.35 0.35 Initial condition for soil water content (m**3/m**3)
0.0 Capillary rise from lower boundary layer, yes(1.0) or no (0.0)
0.43 Water content of lower soil boundary layer in spring (m**3/m**3)
0.38 Water content of lower soil boundary layer in autumn (m**3/m**3)
283.29 Average temperature of lower soil boundary layer (K)
7.6 Amplitude of temperature of lower soil boundary layer (K)
3.89 Phase of temperature of lower soil boundary layer (rad)
0.00000145 NH4+ Deposition other than gaseous NH3 (kg N m-2 d-1)
0.00000151 NO3- Deposition (kg N m-2 d-1)
0 Dates of cutting and grazing calc. by model (1) or on input (0)
9.0 Potential eating rate for lactating cows (kg/(GVE*m**2))
400.0 Weight of lactating cows (kg)
3 Type of animal 1=dairy cows/ 2=suckler cows /3=old module for dairy cows
125 Calving date for dairy or suckler livestock systems (d)
280 Suckling period for suckler livestock systems(d)
280 Age of the calves exit for suckler livestock systems(d)
0.19 Proportion of young suckler cows (3 or 4 years old) or primipare dairy cow
60.25 Calf birth weight for suckler livestock systems(kg)
10.10 Maximum theoretical milk production (kg/animal/d)
0.125 Quantity of concentrate provided per kg of milk (kg DM/kg of milk)
1.09 Concentrate energy value (UE/kg)
0.91 Forage energy value (UE/kg)
0.96 Forage fill value (UE/kg)
0.120 N fraction in the forage (kg N/kg)
0.120 N fraction in the concentrate (kg N/kg)
625.0 650.0 Live weight of cows for autogestion (first:young, second:Mature)
2.5 2.5 Body score condition of cows for autogestion (first:young, second:Mature)
32.0 44.0 Age of cows for autogestion (first:young, second:Mature) in months

```

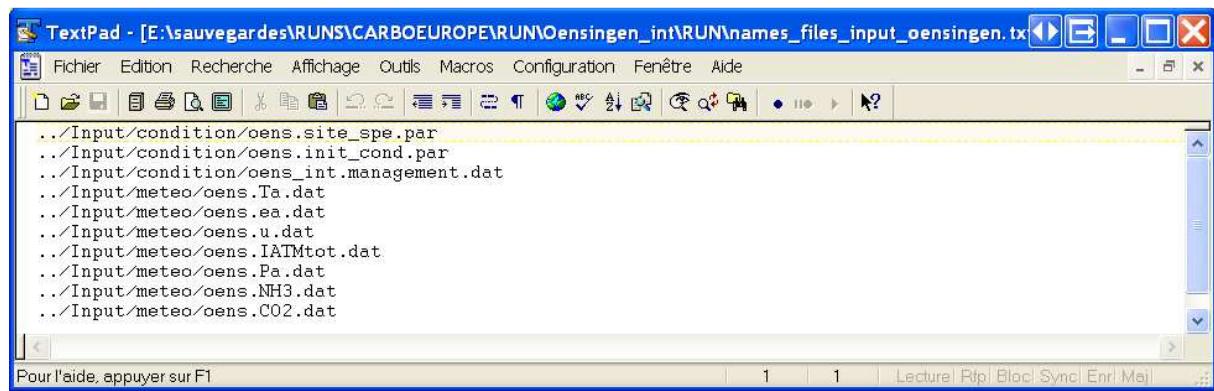
**Figure 4: Example of an initial conditions file**



## 2.1.2 Names input file

This file (**figure 5**) contains the path and the name of management, initial and site specific conditions as well as weather data file. This information must respect the following order:

- Site specific conditions file
- Initial conditions file
- Management file
- Air temperature data file
- Water vapour pressure data file
- Wind speed data file
- Global radiation data file
- Precipitation data file
- NH<sub>3</sub> data file
- CO<sub>2</sub> data file



```
.../Input/condition/oens.site_spe.par
.../Input/condition/oens.init_cond.par
.../Input/condition/oens_int.management.dat
.../Input/meteo/oens.Ta.dat
.../Input/meteo/oens.ea.dat
.../Input/meteo/oens.u.dat
.../Input/meteo/oens.IATMtot.dat
.../Input/meteo/oens.Pa.dat
.../Input/meteo/oens.NH3.dat
.../Input/meteo/oens.CO2.dat
```

**Figure 5: Example of a names input file**

## A) First part

PARAMETER	DESCRIPTION	HELP	ADVISED VALUE
TSTART=	Beginning of the simulation (Julian day)	01 for the simulation to begin the 1 <sup>st</sup> of January of the first year	01
TSTOP=	End of the simulation (Julian day)	365 for the simulation to stop the 31 <sup>st</sup> December of the first year	
INPUT_FILE=	Path of the names input file		
CYCLE_METEO=	Number of meteorological cycles		
CYCLE_GESTION=	Number of management cycles	Same annual management can be repeated several years	
DT=	Time step of most of PaSim processes (day)	Keep 0.02	0.02
DT_DENIT=	Time step for denitrification processes (day)	Keep 0.00025	0.00025
SOILWATERINT=	Time step for water processes (percolation, day)	Keep 0.02	0.02
FLAG_READ_METEO=	When activated meteorological data must be daily data (see 4.1. for more details)	Must be 1 to use daily meteorological data	0
HISTORY_VAR=	Path of the pasimvar file		
HISTORY_NAME=	Variables chosen among the pasimvar file list	Each name must be separated by one space (not more, no tabulation).	
HISTORY=	Path and name of the output file	86400 for a daily frequency	86400
HISTORY_WRT_FREQ=	Frequency of variable output (s)	Better keep the reference value	1728
HISTORY_CALC_FREQ=	Frequency of variable calculation (s)	It must be specified for each of the output variables. Each output criteria must be separated by one space (not more, no tabulation).	
HISTORY_CALCUL=	Specify how the variable is calculated: For example, if you have chosen a daily frequency of variable output, PaSim will output (i) the variable at the end of the day if "NONE", (ii) the daily average variable if "AVE" and (iii) the daily cumulated variable if "SUM".		
WRITE=	"ALL" for all the simulated years to be written in the output file or "LAST_TURN" for only the last year output values in the output file	Choosing "LAST_TURN" for SOM equilibrium simulations allows gaining time.	
SORTIE=	Output format: ASCII or NETCDF	NETCDF format is used for spatial simulations. Must be 1!	ASCII
DENITRIF=	Option that activates denitrification		1
FLAG_LAISTRESS=	Option that activates limitation of vegetation turnover rates driven by Leaf Area Index (LAI).		1
FLAG_WATERSTRESS=	Option that activates water limitation effect on vegetation age dynamics (turnover).		1
FLAG_AGESTRESS=	Age-dependent senescence		1
FLAG_MORTAGRAZ=	Option that activates trampling impact on vegetation turnover		1
FLAG_PLOUGHING=	Option that activates tillage effect on SOM mineralization. If activated do not forget to adjust PARAM_FREQ_PLOUGHING.	Put 0 for permanent grassland and 1 for sown grasslands. In the latter case you also have to specify the tillage frequency.	0
DYN_LEGUME=	Actives legume dynamic	Should be kept to 0 as not operational in this version	0
FLAG_IRRIGATION=	When activated, the model will manage irrigation to satisfy canopy water needs, on the basis on water stress index.		0
FLAG_FERTILIZATION=	When activated, the model will manage mineral nitrogen fertilization to satisfy canopy nitrogen needs, on the basis of nitrogen nutrition index.		0
FLAG_AUTOGESTION=	When activated, mowing (when set to 1) or grazing (when set to 2) is managed by the model.	This option is used for stocking rate and grazing coverage optimization at the forage system scale on one meteorological cycle. FLAG_AUTOGESTION=2 implies iterative runs on each meteorological cycle.	0
FLAG_SATURANT	Needed for auto-management of [Vuichard et al., 2007]	Should not be used anymore	0
FLAG_NONLIMITANT	Needed for auto-management of [Vuichard et al., 2007]	Should not be used anymore	0
FLAG_COMPLEMENTATION	0: No supplementation 1: Prescribed forage supplementation 2: Prescribed concentrate supplementation 3: Prescribed forage and concentrate supplementation 4: Automatic supplementation) (forage and concentrate for suckler and dairy cattle, respectively)	This feature is still in implementation and not validated yet, and so should not be used yet	0
FLAG_DIFF=	0: old way to calculate N <sub>2</sub> O diffusion 1: activate N <sub>2</sub> O diffusion calculated by Crank Nicolson method	Due to computation time prefer use old method during equilibrium research and Crank Nicolson method for other simulations	1
FLAG_EQUILIBRE=	0: No equilibrium research 1: Iterative method of SOM equilibrium 3: Algebraic method of SOM equilibrium		
SOMITERMIN=	Minimum number of steps required to reach SOM equilibrium with climate and management		1
SOMITERMAX=	Maximum number of steps required to reach SOM equilibrium with climate and management		1000

Table 5: Description of information needed in the run file

### 2.1.3 PASIM run file

This file contains the different modalities of simulation:

- **basic**
- time step calculation
- **modalities for SOM equilibrium**
- output variables
- **options of simulation**
- **automatic management**
- **specific parameters for vegetation**
- **spatialization**

The order of the lines does not matter and most of the parameters or options have advised values in code, if they are not in PaSim file.

To know the list of possible output variables you can refer to the pasimvar file (**Annexe 3**).

## 2.2 How to run PaSim

### 2.2.1 General settings and standard single-year simulations

Before PaSim can be run, it is necessary to make sure that all necessary files exist and have been defined for your own simulation:

- All input files (**Section 2.1.1**)
- The pasimvar file updated according to paSim executable
- The PaSim run file (**Section 2.1.3**) ; ex: site.pasim
- The file containing the list of input file path
- The executable 'pasim.exe'

Then, PaSim can be launched by using the following command:

```
pasim.exe site.pasim
```

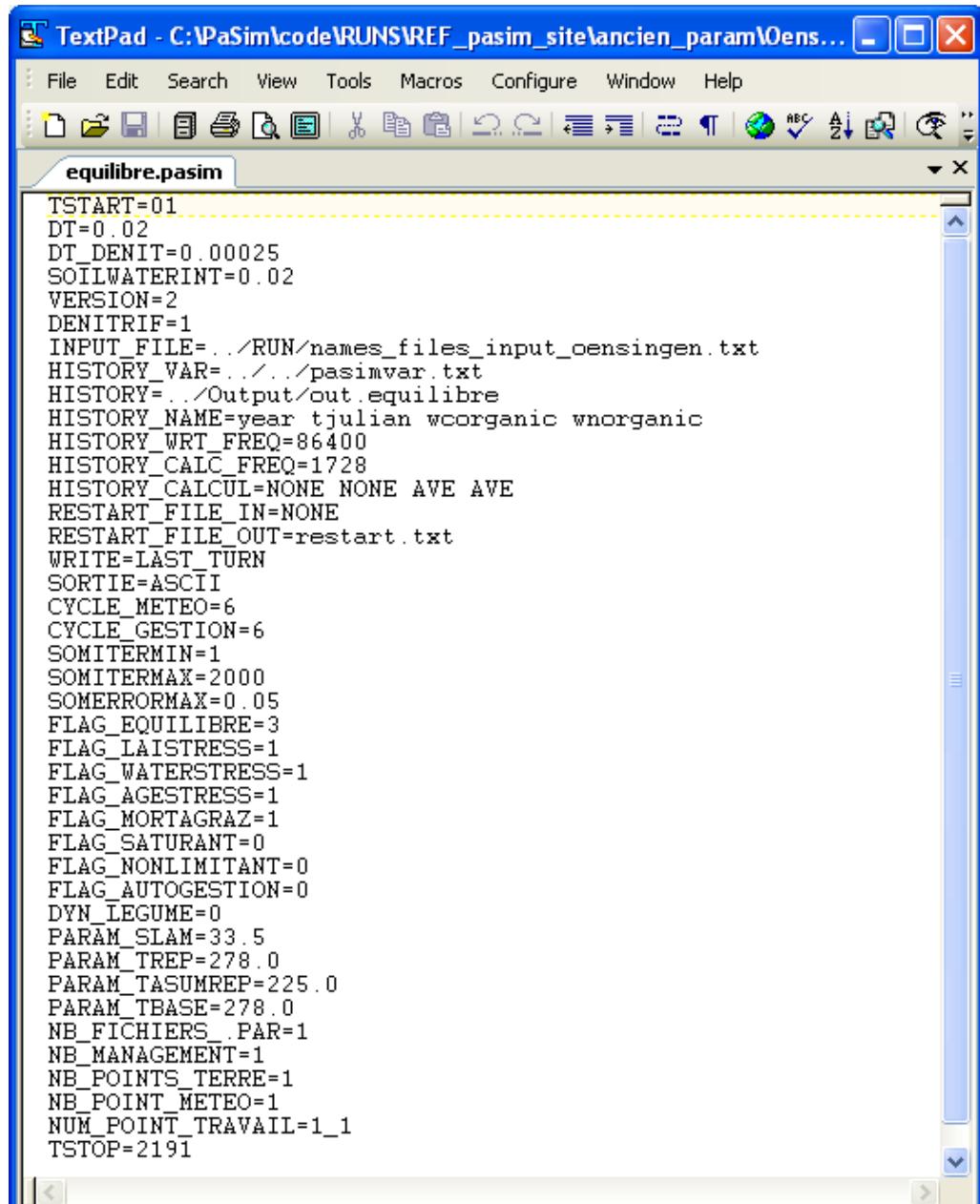
### 2.2.2 Multi-year simulations

As compared to a standard single-year simulation, the setup of a multi-year simulation requires only two additional steps:

- **Setting the parameter TSTOP** at the total number of days to be simulated, e.g. TSTOP = 3650 + 1 (to ensure PaSim will write the last year) for a 10-years simulation. *NB: PaSim does not simulate bissextile years.*
- **Setting the parameter CYCLE\_METEO** at the number of years simulated, e.g. CYCLE\_METEO = 10 in the previous example.

## B) Second part

SOMERRORMAX=	Criteria to stop SOM equilibrium search	Use when initial conditions for SOM are unknown. Else put NONE. Used in equilibrium search; Put NONE when running the model from SOM equilibrium or measurements values.	0.05
RESTART_FILE_IN=	Name of the restart file obtained at SOM equilibrium and which will initialize the model instead of the initial condition input file		
RESTART_FILE_OUT=	Name of the restart file obtained after running the model to reach SOM equilibrium and which will initialized the model instead of "condition input file" file		
PARAM_SLAM=	Maximum specific leaf area ( $m^2.kg^{-1}$ )		
PARAM_TREP=	Parameter for the calculation of plant development		
PARAM_FCLOVER	Legume fraction		
PARAM_ZETA	Specific lamina area constant (kg (kg C)-1)		
PARAM_SSSTA	Specific stem and sheaths area ( $m^2 kg^{-1}$ )		
PARAM_KCN	Michaelis Menten constant for the legume fraction calculation(kgC/kgN)		
PARAM_FNREF	parameter controlling nitrogen concentration of structural dry matter (kg N / kg)		0.022
PARAM_CWPL	Parameter for the calculation of water conductivity between root and shoot (kg water/kg dry matter)(J.kg water)-1.d-1		5.e-3
PARAM_HCANHALF	canopy height parameter		4
PARAM_UNSIGMA20	Root activity parameter (kg N.kg-1 d-1)		0.05
PARAM_FREQ_PLOUGHING	! Tillage Frequency (year-1) , $0 < f_{tillage} < 1$		1.0
PARAM_TASUMREP=	Normalization factor for development (Kd)		225
PARAM_TBASE=	Basal temperature for plant growth (K)		278.15
PARAM_NDFEAR=	Fraction of fibres in the total ear ingested (%)		0.610
PARAM_NDFLAM=	Fraction of fibres in the total lam ingested (%)		0.570
PARAM_NDFSTEM=	Fraction of fibres in the total stem and sheaths ingested (%)		0.590
PARAM_HCANMAX=	Flowering plant height, highest leaf not elongated (m)		0.64
PARAM_NTOTMAX=	Maximum of the total nitrogen concentration in plant (kg N. $kg^{-1}$ )		0.035
PARAM_KTURNRT20=	Rate parameter for root turnover at 20°C (d <sup>-1</sup> )		0.015
PARAM_KTURNSH20=	Rate parameter for shoot turnover at 20°C (d <sup>-1</sup> )		0.05
PARAM_FCSH=	Fractional C content of shoot structural dry matter (kg C.kg <sup>-1</sup> )		0.39
PARAM_FCR=	Fractional C content of root structural dry matter (kg C.kg <sup>-1</sup> )		0.5
PARAM_DAH=	Soil depth below which there is neither plant N uptake, nor soil texture effect of active SOM decomposition (m)		0.20
PARAM_DEVEAR=	Development stage at which ear emergence starts		0.52
FLAG_ROOT_PROFILE	Activate autocalculation of root profile		1
B_ROOT_PROFILE	Parameter b used in calculation of root profile (-)	Useless if FLAG_ROOT_PROFILE = 0	6
PARAM_FROOT	Fraction of structural dry root matter in soil layer h (one value per soil layer)		0.095 0.297 0.238 0.145
PARAM_PMC02VEG	Light-saturated leaf photosynthetic rate at 20°C for vegetative stage (μmol.m <sup>-2</sup> .s <sup>-1</sup> )		0.195 0.030
PARAM_PMC02REP	Light-saturated leaf photosynthetic rate at 20°C for reproductive stage (μmol.m <sup>-2</sup> .s <sup>-1</sup> )		15 22.47
PARAM_A_NH4	Parameter a for soil NH4+ partitioning		22.6 33.95
PARAM_B_NH4	Parameter b for soil NH4+ partitioning		1.076
PARAM_YIELDLOSS	Parameter to specify loss fraction at cutting events (-)		0.66
PARAM_DNDFLAM[1-4],	Fraction of digestible fibers in total fibers, in age class (1 to 4) of lamina (-)		0.05
PARAM_DNDFSTEM[1-4],	Fraction of digestible fibers in total fibers, in age class (1 to 4) of stem (-)		
PARAM_DNDFEAR[1-4],	Fraction of digestible fibers in total fibers, in age class (1 to 4) of ear (-)		
NB_FICHIERS_PAR=	Number of PaSim files for spatialized simulations		1
NB_POINTS_TERRE=	Number of grid points for spatialized simulations		1
NB_POINT_METEO=	Number of possible grid points for spatialized simulations ( $\geq$ NB_POINTS_TERRE)		1
NUM_POINT_TRAVAIL=	Number of the grid point that will be run		1_1



The screenshot shows a TextPad editor window with the file 'equilibre.pasim' open. The window has a standard menu bar with File, Edit, Search, View, Tools, Macros, Configure, Window, and Help. Below the menu is a toolbar with various icons for file operations like Open, Save, Find, and Print. The main text area contains a configuration file for a simulation. The file includes parameters such as TSTART, DT, DT\_DENIT, SOILWATERINT, VERSION, DENITRIF, INPUT\_FILE, HISTORY\_VAR, HISTORY, HISTORY\_NAME, HISTORY\_WRT\_FREQ, HISTORY\_CALC\_FREQ, HISTORY\_CALCUL, RESTART\_FILE\_IN, RESTART\_FILE\_OUT, WRITE, SORTIE, CYCLE\_METEO, CYCLE\_GESTION, SOMITERMIN, SOMITERMAX, SOMERRORMAX, FLAG\_EQUILIBRE, FLAG\_LAISTRESS, FLAG\_WATERSTRESS, FLAG\_AGESTRESS, FLAG\_MORTAGRAZ, FLAG\_SATURANT, FLAG\_NONLIMITANT, FLAG\_AUTOGESTION, DYN\_LEGUME, PARAM\_SIAM, PARAM\_TREP, PARAM\_TASUMREP, PARAM\_TBASE, NB\_FICHIERS\_PAR, NB\_MANAGEMENT, NB\_POINTS\_TERRE, NB\_POINT\_METEO, NUM\_POINT\_TRAVAIL, and TSTOP. The file ends with a timestamp of 2191.

```
TSTART=01
DT=0.02
DT_DENIT=0.00025
SOILWATERINT=0.02
VERSION=2
DENITRIF=1
INPUT_FILE=../RUN/names_files_input_oensingen.txt
HISTORY_VAR=../pasimvar.txt
HISTORY=../Output/out_equilibre
HISTORY_NAME=year t Julian worganic wnorganic
HISTORY_WRT_FREQ=86400
HISTORY_CALC_FREQ=1728
HISTORY_CALCUL=NONE NONE AVE AVE
RESTART_FILE_IN=NONE
RESTART_FILE_OUT=restart.txt
WRITE=LAST_TURN
SORTIE=ASCII
CYCLE_METEO=6
CYCLE_GESTION=6
SOMITERMIN=1
SOMITERMAX=2000
SOMERRORMAX=0.05
FLAG_EQUILIBRE=3
FLAG_LAISTRESS=1
FLAG_WATERSTRESS=1
FLAG_AGESTRESS=1
FLAG_MORTAGRAZ=1
FLAG_SATURANT=0
FLAG_NONLIMITANT=0
FLAG_AUTOGESTION=0
DYN_LEGUME=0
PARAM_SIAM=33.5
PARAM_TREP=278.0
PARAM_TASUMREP=225.0
PARAM_TBASE=278.0
NB_FICHIERS_PAR=1
NB_MANAGEMENT=1
NB_POINTS_TERRE=1
NB_POINT_METEO=1
NUM_POINT_TRAVAIL=1_1
TSTOP=2191
```

**Figure 6: Example of a run file**



### 2.2.3 Steady-state simulations

The parameters and variables required in initial conditions file (see Section 2.1.1.4) are usually not all available. Among others, **getting information about the C- and N-content in the different soil pools is very difficult**. To overcome this difficulty, it is possible to let PaSim generate **equilibrium values** of these parameters and variables through a so-called **steady-state simulation**.

The basic steps to run a steady-state simulation are the same as for a standard simulation, the only difference being in the **settings of certain parameters** in the PaSim run file (see Section 2.1.3):

- **FLAG\_EQUIBRE=1** or **FLAG\_EQUIBRE=3** (to use either iterative or matrix method)
- **RESTART\_FILE\_IN=NONE**
- **RESTART\_FILE\_OUT=Restart.txt** (for instance)
- **CYCLE\_METEO**: the number of years to be simulated  
e.g. CYCLE\_METEO=3 means that SOM equilibrium would be searched for 3 years of the time-series
- **SOMERRORMAX**: termination criterium i.e. the tolerated error when reaching C- and N-balance steady states expressed in percent of the considered balance
- **SOMITERMIN**: minimum number of iterations
- **SOMITERMAX**: maximum number of iterations
- **TSTART**: Specify the first day of the time-series on which SOM steady-state will be searched for (e.g. 366 to start at the second year of the series)
- **TSTOP**: his value has no importance when searching for equilibrium

## 2.3 Specific PaSim simulations

### 2.3.1 Optimal grazing coverage and stocking rate

#### 2.3.1.1 How does it work?

**Vuichard et al (2007a)** developed a two-step procedure to assess the optimal fractional coverage of grazing and the associated stocking rate at the forage system scale.

First, PaSim simulates a cut meadow and optimizes cutting events and mineral N fertilization to determine the optimal forage yield. In this way, it estimates the available forage resources ( $Y$ ) to feed animals at barn.

Second, the model simulates a grazed pasture and, according to  $Y$ , it increments the instantaneous stocking rate ( $S$ ) until an equilibrium between forage resources ( $Y$ ) and forage needs ( $X$ ) is reached while accounting for available surfaces for either mowing ( $1-F$ ) or grazing ( $F$ ) (Figure 7).  $X$  is calculated as the product of the number of days animals spend at barn ( $N_B$ ) by the average intake capacity ( $CI$ ) of animals at barn (assumed to be  $15.5 \text{ kg DM animal}^{-1} \text{ d}^{-1}$ ) and  $S$ .

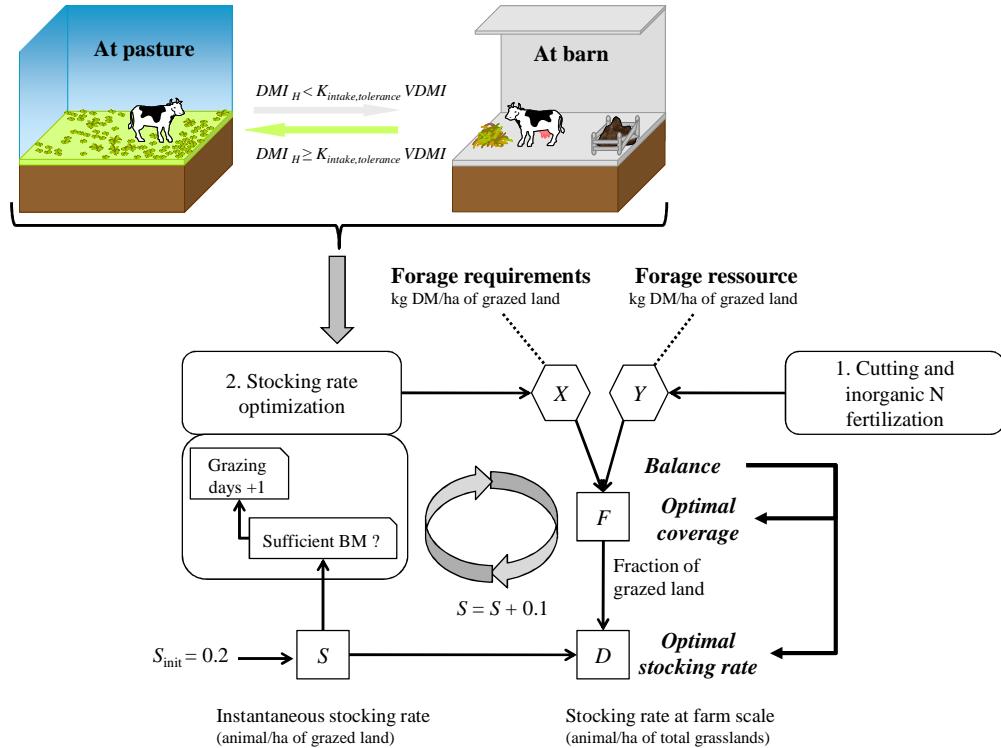
The procedure stops when (with a tolerated error of 1%):

$$Y(1-F) = X = N_B \cdot CI \cdot S$$



Using  $F$  and  $S$  values, the procedure allows calculating the stocking rate ( $D$ ) per ha of total grassland surfaces:

$$D = FS \quad (8)$$



**Figure 7: Procedure used in PaSim to optimize stocking rates and fractional coverage of cut and grazed grasslands**

When mowing is simulated, cutting events are function of plant growth and occur every 30 or more days: after 30 days of regrowth, a new cut is triggered whenever plant growth rate declines during 10 consecutive days.

When grazing is simulated, it starts when herbage dry matter intake ( $DMI_H$ ) is above a fixed fraction of the potential intake ( $VDMI$ ), which reflects herbage biomass availability. This fraction ( $K_{intake,tolerance}$ ) is assumed to depend upon farmer's attitude to animal herbage deprivation and is therefore a parameter of the model. When  $DMI_H$  drops below " $K_{intake,tolerance} \times VDMI$ ", grazing stops and animals are considered at barn. To avoid numerical instability, grazing resumes when  $DMI_H$  becomes greater than " $K_{intake,tolerance} \times VDMI + 0.1$ " and after a minimum 15-day delay between two consecutive periods. In so doing, the procedure gives the number of days when animals are at pasture ( $N_P$ ) and consequently at barn ( $N_B$ ).

Contrary to **Vuichard et al. (2007a)**, who also used a two-step procedure to optimize mineral N fertilization (with, first, soil N saturation, and then N fertilization limitation), the latter is optimized with a one step-procedure based on nitrogen nutrition index (**Graux, 2011**).

Some limitations can be highlighted:

- (i) As PaSim does not simulate animal processes at barn, the latter are estimated.
- (ii) Neither mixed management (cutting and grazing) in a given paddock, nor between year forage stock use is considered.
- (iii) Livestock systems are assumed self-sufficient in terms of feed supply (during housing, animals are fed with hay derived from the cut herbage).



### 2.3.2 How to run the procedure for optimal grazing coverage and stocking rate

In the following example, optimal grazing coverage and stocking rate of 'site1' are optimized on two successive meteorological years, for instance 'year1' and 'year2'.

For running the first step (automatic cutting and N fertilization) on year1,

1° you have to create:

- 1 PaSim specific run file, e.g. site1\_year1\_cut.pasim
- 1 specific management file, e.g. site1\_year1.management\_cut.dat
- 1 specific file for input data file paths e.g. names\_files\_input\_site1\_year1\_cut.txt

The management file for automatic cutting (e.g. site\_year1.management\_cut.dat) must have the following information (still 180 columns):

tcut	500 500 500 500 500 500 500 500 500 500 500
tfert	500 500 500 500 500 500 500 500 500 500 500
Nfertamm	0 0 0 0 0 0 0 0 0 0 0
Nfertnit	0 0 0 0 0 0 0 0 0 0 0
Nanimal	0 0 0 0 0 0 0 0 0 0 0
tanimal	500 500 500 500 500 500 500 500 500 500 500
danimal	0 0 0 0 0 0 0 0 0 0 0
Nliqmanure	0 0 0 0 0 0 0 0 0 0 0
Nslurry	0 0 0 0 0 0 0 0 0 0 0
Nsolmanure	0 0 0 0 0 0 0 0 0 0 0
LWYcows	0 0 0 0 0 0 0 0 0 0 0
LWMcows	0 0 0 0 0 0 0 0 0 0 0
BCSYcows	0 0 0 0 0 0 0 0 0 0 0
BCSMcows	0 0 0 0 0 0 0 0 0 0 0
LWcalves	0 0 0 0 0 0 0 0 0 0 0
AGE_cow_P	0 0 0 0 0 0 0 0 0 0 0
AGE_cow_M	0 0 0 0 0 0 0 0 0 0 0
Forage quantity	0 0 0 0 0 0 0 0 0 0 0

The specific file for the input data file paths (e.g. names\_files\_input\_site1\_year1\_cut.txt) must have the following form:

```
./Input/conditions/site1.site_spe.par
./Input/conditions/site1.init_cond.par
./Input/conditions/site1_year1.management_cut.dat
./Input/meteo/Ta.dat
./Input/meteo/ea.dat
./Input/meteo/u.dat
./Input/meteo/IATMtot.dat
./Input/meteo/Pa.dat
./Input/meteo/NH3.dat
./Input/meteo/CO2.dat
```



2° In the PaSim run file you have activate:

- FLAG\_FERTILIZATION=1
- FLAG\_AUTOGESTION=1
- RESTART\_FILE\_IN=restart.txt
- RESTART\_FILE\_OUT=restart\_site1\_year1\_cut.txt

and to specify the path of the 'names\_files\_input\_site1\_year1\_cut.txt' file

At the end of the simulation (which does not last more than a single year simulation) PaSim creates a new file which contains the optimal forage DM yield. This file is in the same directory than those of the automatic cutting management file. The name of this file is derived from those of the automatic cutting management file by adding '\_yield\_inn' at its end, e.g. site1\_year1.management\_cut\_yield\_inn.dat

*NB: Values of the forage DM yield must divided by 10<sup>3</sup> to be converted into t DM ha<sup>-1</sup>*

For running the second step (automatic grazing) on year1,

1° you have to create:

- 1 PaSim specific run file, e.g. site1\_year1\_graz.pasim
- 1 specific management file, e.g. site1\_year1.management\_graz.dat
- 1 specific file for input data file paths e.g. names\_files\_input\_site1\_year1\_graz.txt

The management file for automatic grazing (e.g. site\_year1.management\_graz.dat) must have the following information (still 180 columns):

tcut	500 500 500 500 500 500 500 500 500 500 500 500
tfert	500 500 500 500 500 500 500 500 500 500 500 500
Nfertamm	0 0 0 0 0 0 0 0 0 0 0 0
Nfertnit	0 0 0 0 0 0 0 0 0 0 0 0
Nanimal	0 0 0 0 0 0 0 0 0 0 0 0
tanimal	500 500 500 500 500 500 500 500 500 500 500 500
danimal	0 0 0 0 0 0 0 0 0 0 0 0
Nliqmanure	0 0 0 0 0 0 0 0 0 0 0 0
Nslurry	0 0 0 0 0 0 0 0 0 0 0 0
Nsolmanure	0 0 0 0 0 0 0 0 0 0 0 0
LWYcows	0 0 0 0 0 0 0 0 0 0 0 0
LWMcows	0 0 0 0 0 0 0 0 0 0 0 0
BCSYcows	0 0 0 0 0 0 0 0 0 0 0 0
BCSMcows	0 0 0 0 0 0 0 0 0 0 0 0
LWcalves	0 0 0 0 0 0 0 0 0 0 0 0
AGE_cow_P	0 0 0 0 0 0 0 0 0 0 0 0
AGE_cow_M	0 0 0 0 0 0 0 0 0 0 0 0
Forage quantity	0 0 0 0 0 0 0 0 0 0 0 0



The specific file for the input data file paths (e.g. names\_files\_input\_site1\_year1\_graz.txt) must have the following form:

```
./Input/conditions/site1_.site_spe.par  
./Input/conditions/site1.init_cond.par  
./Input/conditions/site1_year1.management_graz.dat  
./Input/meteo/Ta.dat  
./Input/meteo/ea.dat  
./Input/meteo/u.dat  
./Input/meteo/IATMtot.dat  
./Input/meteo/Pa.dat  
./Input/meteo/NH3.dat  
./Input/meteo/CO2.dat  
./Input/conditions/site1_year1.management_cut_yield_inn.dat
```

2° In the PaSim run file you have activate:

- FLAG\_FERTILIZATION=1
- FLAG\_AUTOGESTION=2
- RESTART\_FILE\_IN=restart.txt
- RESTART\_FILE\_OUT=restart\_site1\_year1\_graz.txt

and to specify the path of the 'names\_files\_input\_site1\_year1\_graz.txt' file

This simulation lasts more than a single year simulation as PaSim searches for equilibrium between forage resources and cattle forage needs at barn by iterative runs.

At the end of the simulation, PaSim creates a new file which contains, in that order:

- (i) Proportion of forage requirements relatively to the forage available (-)
- (ii) Fractional grazing coverage (-)
- (ii) Number of days spent at pasture (d)
- (iv) Optimal stocking rate (animal (ha of total grasslands)<sup>-1</sup>)

The name of this file is created from the name of the management file for automatic grazing by adding '\_inn' at the end, e.g. site1\_year1.management\_graz\_inn.dat

Repeat these two steps for the following year 'year2' by replacing 'year1' by 'year2' and by specifying Restart files in PaSim run files:

For automatic cutting:

- RESTART\_FILE\_IN= restart\_site1\_year1\_cut.txt
- RESTART\_FILE\_OUT=restart\_site1\_year2\_cut.txt

For automatic grazing:

- RESTART\_FILE\_IN= restart\_site1\_year1\_graz.txt
- RESTART\_FILE\_OUT=restart\_site1\_year2\_graz.txt

You may imagine to simulate more than two successive years.



### 2.3.3 Modelling $^{14}\text{C}$ and $^{13}\text{C}$ cycles with PaSim

PaSim can be used to simulate the dynamics of 2 radioactive isotopes of the carbon, in addition to the  $^{12}\text{C}$ :  $^{13}\text{C}$  and  $^{14}\text{C}$ .

In order to do this, the user has to:

- Create a meteorological file for the considered isotope , in  $\text{Bq} (\text{kg C})^{-1}$  for  $\text{C}^{14}$  or in % for  $\text{C}^{13}$  (like other meteorological files). Note that only one of the isotopes can be simulated at the time.
- Add the location of this meteorological file in the names input file, just after the path of the basic CO2 file
- Specify FLAG\_ISOTOPE value in the PaSim run file:
  - FLAG\_ISOTOPE=0: only  $^{12}\text{C}$
  - FLAG\_ISOTOPE=1:  $^{12}\text{C}$  and  $^{14}\text{C}$
  - FLAG\_ISOTOPE=2:  $^{12}\text{C}$  and  $^{13}\text{C}$
- Possibly add FLAG\_DISINTEGRATION=1 in the PaSim run file if you want to activate disintegration (only for  $^{14}\text{C}$ )

When simulating  $^{14}\text{C}$  and  $^{13}\text{C}$  cycles, the structure of the restart file will change (see Annexe 5).



### 3 Graphical User Interface

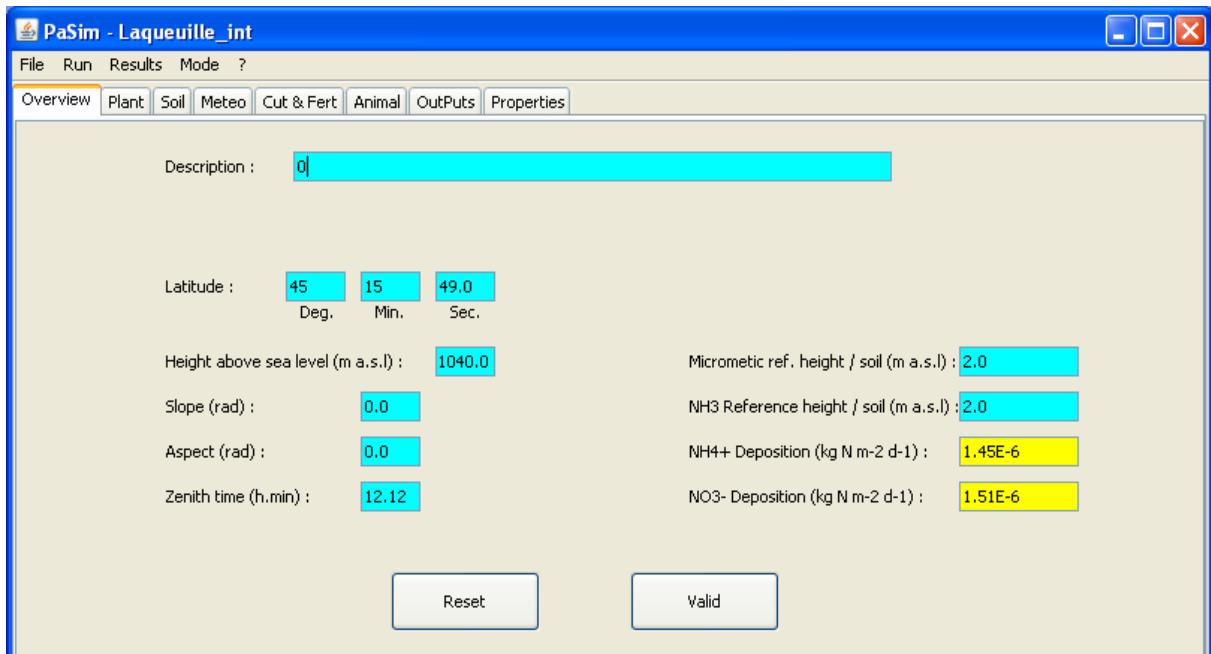
It is possible to use PaSim with its graphical interface. It allows the user to create or to modify files needed for a simulation. It also allows to run PaSim and to have results in an xls file.

In this interface there are eight tabs (or nine if the user wants to use the sensibility analyse interface). The six first tabs correspond to a specific part of the grassland properties, such as the soil or the animals. The two others tabs are related to PaSim: the user can choose which outputs he wants, with a graphic or not, and select the properties of the simulation. All of this will be explain in the following sections.

In order to help the creation of grassland, a default value is proposed for most of the parameters the user has to fill. These values are the “advised values” present in the tables of this user guide.

In each tab there is a “valid” button which allows the user to save and to check the integrity of the values he fills. There is also a “reset” button which put all the parameters to their default value.

#### 3.1 The overview tab



**Figure 8: Overview tab of the graphical interface**

In this tab the user can fill specifics values of the grassland, such as the latitude or the zenith time.

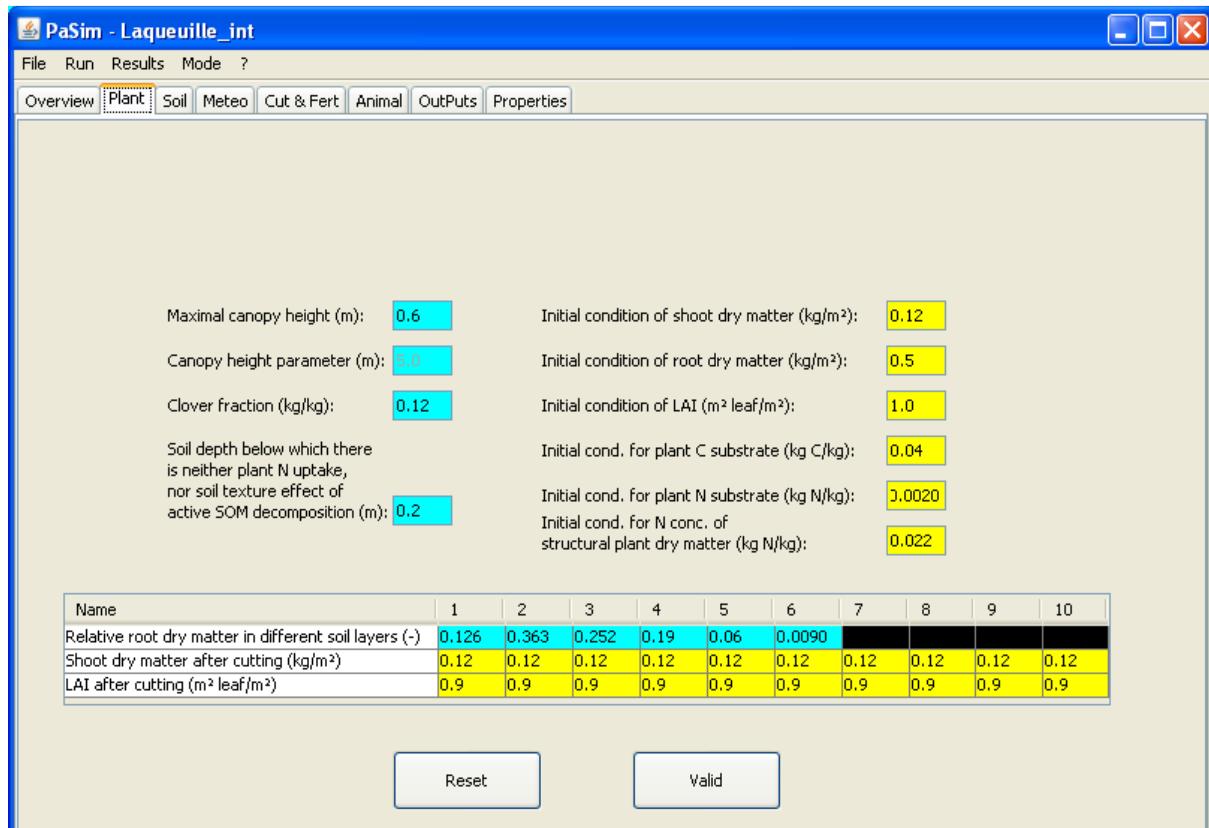
VARIABLE	UNIT	HELP	ADVISED VALUE
Description Latitude N (exemple: 55° 52' 20'')	- rad	[-π/2: π /2] Exemple: (55° +(52'/60) + (20'"/3600))*2 π/360	-
Height above sea level	m a.s.l.		
Slope	rad	[-π: π] or [0:2 π]	0.0
Aspect	rad	[-π: π] or [0:2 π]	0.0
Zenith time	h:min	[0:24]	12.12
Micrometric reference height above soil surface	m a.s.l.		2.0
NH <sub>3</sub> reference height above soil surface	m a.s.l.		2.0
NH <sub>4</sub> <sup>+</sup> deposition other than gaseous NH <sub>3</sub>	kg N m <sup>-2</sup> d <sup>-1</sup>	Prefer default value	0.00000145
NO <sub>3</sub> - deposition	kg N m <sup>-2</sup> d <sup>-1</sup>	Prefer default value	0.00000151

Table 5: the overview tab parameters

VARIABLE	UNIT	HELP	ADVISED VALUE
Maximal canopy height	m		
Canopy height parameter (leaf area index for which canopy is half the maximum canopy height)	m <sup>2</sup> laminae m <sup>-2</sup>	Does not change	4.0
Clover fraction	kg kg <sup>-1</sup>		0.2
Soil depth below which there is neither plant N uptake, nor soil texture effect of active SOM decomposition	m		
Initial condition of shoot dry matter	kg/m <sup>2</sup>		
Initial condition of root dry matter	kg/m <sup>2</sup>		
Initial condition of LAI	m <sup>2</sup> laminae m <sup>-2</sup>		1
Initial cond. for plant C substrate concentration	kg C kg <sup>-1</sup>	Prefer default value	0.04
Initial cond. for plant N substrate concentration	kg N kg <sup>-1</sup>	Prefer default value	0.002
Initial cond. for N conc. of structural plant dry matter	kg N kg <sup>-1</sup>	Prefer default value	0.022
Relative root dry matter in different soil layers	- (fraction)	Sum of all layers has to be 1	
Shoot dry matter after cutting	kg DM m <sup>-2</sup>	10 values	
LAI after cutting	m <sup>2</sup> laminae m <sup>-2</sup>	10 values	

Table 6: the plant tab parameters

## 3.2 The plant tab



**Figure 9: Plant tab of the graphical interface**

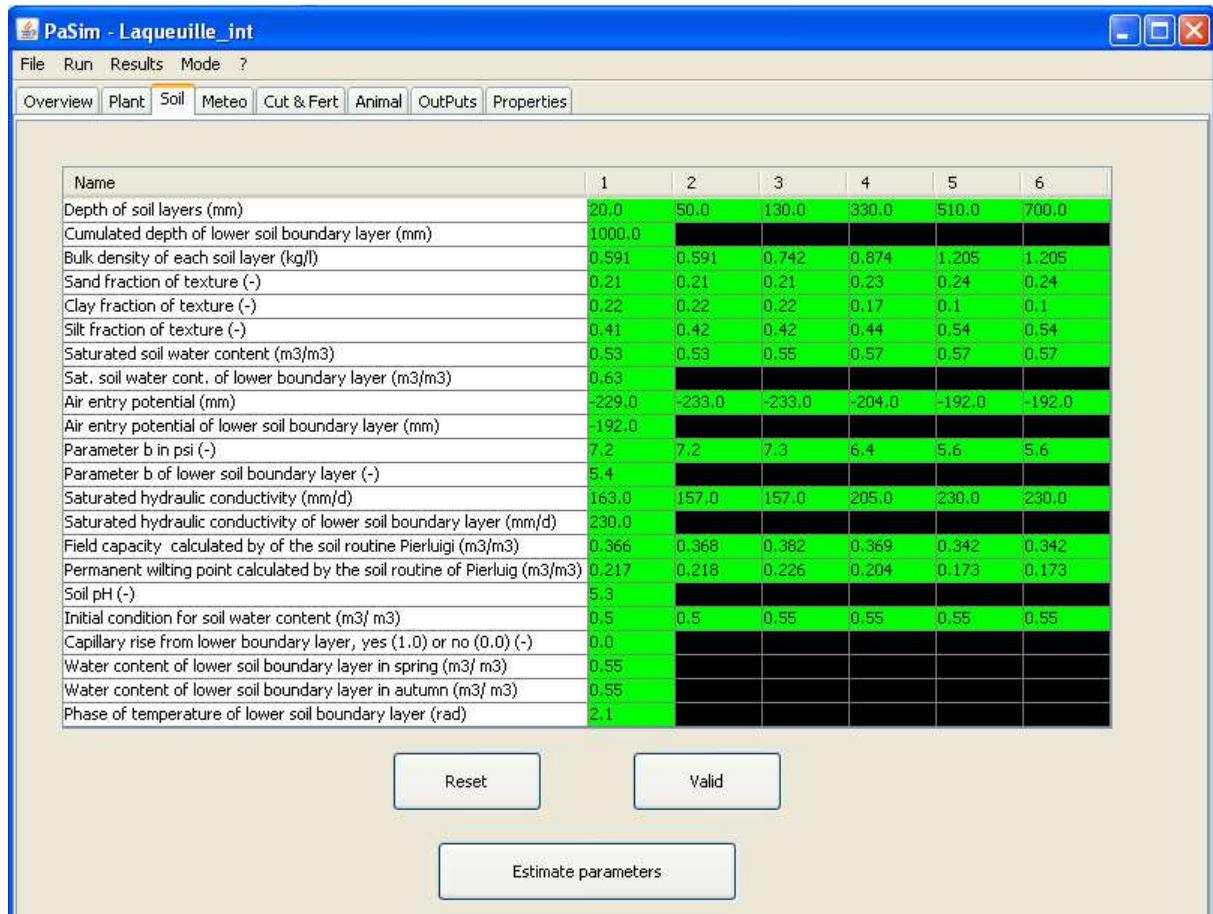
This tab contains all the plant parameters of the grassland. The canopy height parameter cannot be changed in the interface.

VARIABLE	UNIT	HELP	ADVISE D VALUE
Cumulated depth of soil layers	mm	First layer must be 20 mm	
Cumulated depth of lower soil boundary layer	mm	Must be larger than previous soil layer	
Bulk density of each soil layer	kg L <sup>-1</sup>	All the same or increasing values	
Sand fraction of texture	-		
Clay fraction of texture	-		
Silt fraction of texture	-		
Saturated soil water content	m <sup>3</sup> m <sup>-3</sup>	(could be estimated thanks to the following formula 1 -dendity/2.65) Same as last layer	
Saturated soil water content of lower boundary layer	m <sup>3</sup> m <sup>-3</sup>		
Air entry potential*	mm	Use soil routine	
Air entry potential of lower soil boundary layer*	mm	Same as last layer	
Parameter b in psi*	-	Use soil routine	
Parameter b of lower soil boundary layer*	-	Same as last layer	
Saturated hydraulic conductivity*	mm d <sup>-1</sup>	Use soil routine	
Saturated hydraulic conductivity of lower soil boundary layer	mm d <sup>-1</sup>	<b>NOT USED ANYMORE</b>	
Parameter for the determination of the field capacity*		<b>NOT USED ANYMORE</b>	0.01
Field capacity*	m <sup>3</sup> m <sup>-3</sup>	Use soil routine	
Permanent wilting point*	m <sup>3</sup> m <sup>-3</sup>	Use soil routine	
Soil pH	-		7.0
Initial condition for soil water content	m <sup>3</sup> m <sup>-3</sup>	Careful not higher than saturated value	
Capillary rise from lower boundary layer, yes (1.0) or no (0.0)	-		
Water content of lower soil boundary layer in spring	m <sup>3</sup> m <sup>-3</sup>	Should not be higher than saturated value	
Water content of lower soil boundary layer in autumn	m <sup>3</sup> m <sup>-3</sup>	Should not be higher than saturated value	
Phase of temperature of lower soil boundary layer	rad		

\* calculated by of the soil routine of Pierluigi Calanca

Table 7: the soil tab parameters

### 3.3 The soil tab



**Figure 10: Soil tab of the graphical interface**

In this tab there are all the soil parameters of the grassland. Some of these can't be changed, such as the depth of the first soil layer, which has to be 20 millimetres.

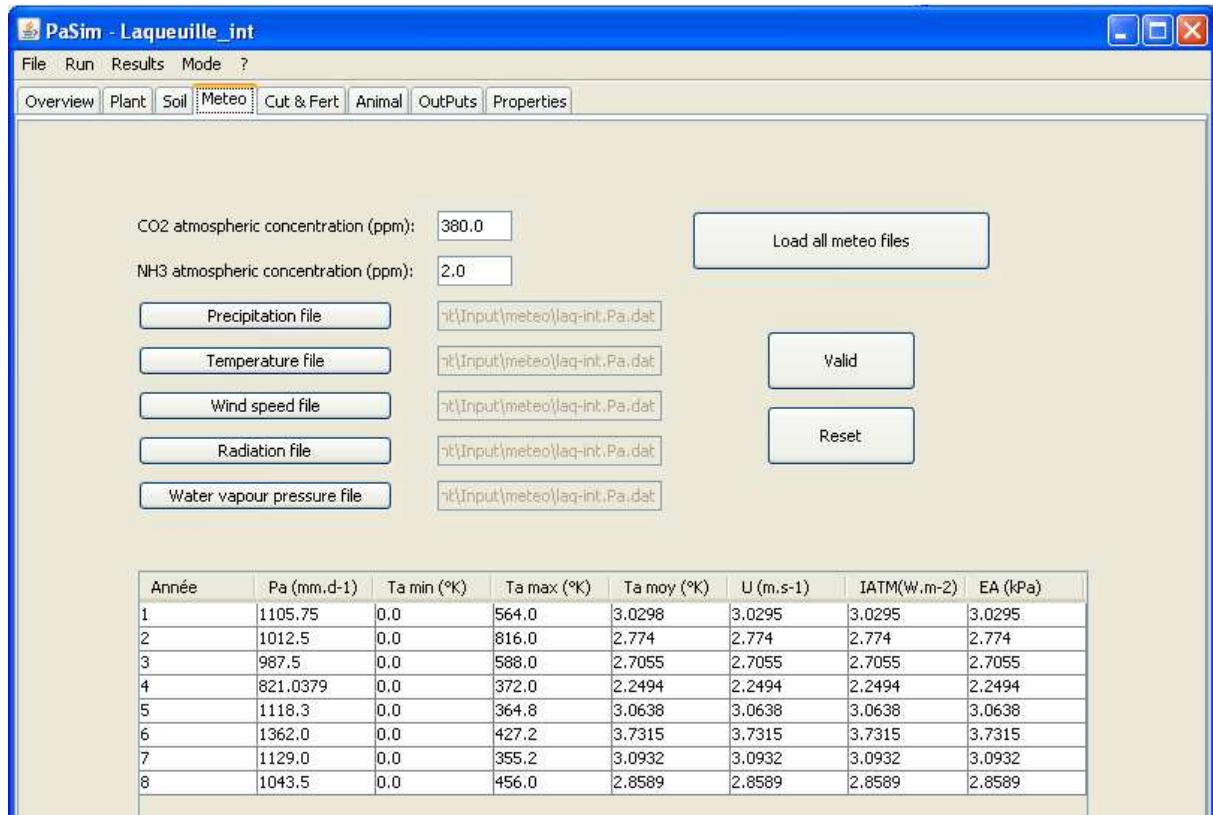
The user can estimate parameters, such as the air entry potential or the parameter b in psi, using other parameters, such as fractions of sand, silt and clay. After that he can choose to report or not the new values into the interface.

## Hourly Data

VARIABLE	DESCRIPTION	UNIT	NECESSARY MODIFICATIONS
Pa	Precipitations	mm.d-1	PASIM needs <b>daily weather data at each hourly time step</b> . If precipitations are in mm.h-1, multiply by 24.
Ta	Average air temperature	K	If temperature is in Celsius degrees, add 273,15.
U	Wind speed	m.s-1	-
IATMtot	Radiation	W.m-2	If radiation is in $J\ cm^{-2}$ , divide by 0.36
Ea	Water vapour pressure	kPa	If Relative humidity (RH), use Bolton (1980): $Ea=0,6112.\exp((17,67.Ta)/(Ta+243,5)) * RH/100$ , Where Ta is in $^{\circ}C$
C13	$C^{13}$ concentration	atmospheric	-
C14	$C^{14}$ concentration	atmospheric	Bq/kg C
CO2	$CO_2$ concentration	atmospheric	ppm
NH3	$NH_3$ concentration	atmospheric	ppm

Table 8: the meteo tab parameters.

### 3.4 The meteo tab



**Figure 11: Meteo tab of the graphical interface**

In this tab the user has to load the meteo files associated to the grassland. These files are in the "Meteo" directory of the grassland.

Only the CO<sub>2</sub> and the NH<sub>3</sub> parameters can be changed. They are considered to be constant during the simulation. If not then manually change links to CO<sub>2</sub> or NH<sub>3</sub> files into the "names\_inputs\_file" before running PaSim.

If the user uses the carbon 14 specific interface he also has to load the carbon 14 file.

VARIABLE	DESCRIPTION	UNIT
Tcut	Date of cutting event	Julian day
Tfert	Date of fertilization event	Julian day
Nfertamm	Amount of N-ammonium for each application of mineral fertilizer	kg N m <sup>-2</sup>
Nfertnit	Amount of N-nitrates for each application of mineral fertilizer	kg N m <sup>-2</sup>
Nliqmanure	amount of N in liquid manure	kg N m <sup>-2</sup>
Nslurry	amount of N in slurry	kg N m <sup>-2</sup>
Nsolmanure	amount of N in solid manure	kg N m <sup>-2</sup>

Table 9: the cut and fert. tab parameters.

### 3.5 The Cut and Fert. tab

PaSim - Laqueuille\_int

File Run Results Mode ?

Overview Plant Soil Meteo Cut & Fert Animal Outputs Properties

Number of management years : 8

Cutting event (Julian days) :

Year	1	2	3	4	5	6	7	8	9	10
0	500	500	500	500	500	500	500	500	500	500
1	500	500	500	500	500	500	500	500	500	500
2	500	500	500	500	500	500	500	500	500	500
3	500	500	500	500	500	500	500	500	500	500
4	500	500	500	500	500	500	500	500	500	500

Fertilization event (Julian days) :

Year	1	2	3	4	5	6	7	8	9	10
0	171	500	500	500	500	500	500	500	500	500
1	144	189	500	500	500	500	500	500	500	500
2	144	189	229	500	500	500	500	500	500	500
3	145	189	230	500	500	500	500	500	500	500
4	111	185	220	500	500	500	500	500	500	500

Amount of ammonium for each application of mineral fertilizer (kg.N/m<sup>2</sup>) :

Year	1	2	3	4	5	6	7	8	9	10
0	0.0040	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.00435	0.00435	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.00345	0.00335	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.00355	0.00355	0.0030	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.00355	0.00355	0.00325	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Amount of nitrates for each application of mineral fertilizer (kg.N/m<sup>2</sup>) :

Year	1	2	3	4	5	6	7	8	9	10
0	0.0040	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.00435	0.00435	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.00345	0.00335	0.0020	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.00355	0.00355	0.0030	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.00355	0.00355	0.00325	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Amount of N in liquid manure (kg.N/m<sup>2</sup>) :

Year	1	2	3	4	5	6	7	8	9	10
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Amount of N in slurry (kg.N/m<sup>2</sup>) :

**Figure 12: Cut and Fert tab of the graphical interface**

This tab allows the user to define the cutting and fertilization events. The number of management years is defined in this tab and also affects the next tab: Animal.

VARIABLE	UNIT	HELP	ADVISED VALUE
Potential eating rate of lactating cows	kg DM animal <sup>-1</sup>	only used by old module version	15
Weight of lactating cows	kg	only used by old module version	650
Type of animal	-	1 = dairy cows; 2 = suckler cows 3 = old module (dairy cows) 4 = dairy heifers 5 = suckler heifers 6 = sheep with old module	
Calving date for dairy or suckler livestock system	d	Useless for old module version	
Suckling period for suckler livestock system	d	Useless for old module version	
Age of the calves exit for suckler livestock systems	d	Useless for old module version	
Proportion of young suckler cows (3 or 4 years old) or primiparous dairy cows in the cattle	-	Useless for old module version	0.20
Calf birth Weight for suckler livestock systems	kg	Useless for old module version	45
Milk production at peak for young or primiparous	kg animal <sup>-1</sup> d <sup>-1</sup>	Useless for old module version	8 (suckling), 28 (dairy)
Milk production at peak for mature or multiparous	kg animal <sup>-1</sup> d <sup>-1</sup>	Useless for old module version	10 (suckling), 34 (dairy)
Quantity of concentrate provided per kg of milk	kg DM (kg of milk) <sup>-1</sup>	Useless for old module version	0.125
Concentrate energy value	UF kg <sup>-1</sup>	Useless for old module version	
Forage energy value	UF kg <sup>-1</sup>	Useless for old module version	
Forage fill value	UE kg <sup>-1</sup>	Useless for old module version	
N fraction in the forage	kg N kg <sup>-1</sup>	Useless for old module version	0.120
N fraction in the concentrate	kg N kg <sup>-1</sup>	Useless for old module version	0.120
Initial cow liveweight of for automatic management for young or primiparous	kg	Only used for automatic management	600
Initial cow liveweight of for automatic management for mature or multiparous	kg	Only used for automatic management	650
Initial cow body condition score for automatic management for young or primiparous	-	Only used for automatic management	3
Initial cow body condition score for automatic management for mature or multiparous	-	Only used for automatic management	3
Initial cow age for automatic management for young or primiparous	months	Only used for automatic management	32
Initial cow age for automatic management for mature or multiparous	months	Only used for automatic management	44
Nanimal	Animal m <sup>-2</sup>	stocking rate	
Tanimal	Julian day	start of the grazing period	
Danimal	day	Length of the grazing period	
LWYcows	kg animal <sup>-1</sup>	Initial average live weight of young cows at the beginning of the considered grazing period	
LWMcows	kg animal <sup>-1</sup>	Initial average liveweight of young/primiparous cows at the beginning of the considered grazing period	
BCSYcows	-	Initial average live weight of mature/multiparous cows at the beginning of the considered grazing period	
BCSMcows	-	Initial average body condition score of young/primiparous cows at the beginning of the considered grazing period	
LWcalves	kg animal <sup>-1</sup>	Initial average body condition score of mature/multiparous cows at the beginning of the considered grazing period	
AGE_cow_P	Month	Initial average liveweight of calves at the beginning of the considered grazing period	
AGE_cow_M	Month	Age for primiparous cows at the start of the considered grazing period	
Forage quantity	kg DM animal <sup>-1</sup> day <sup>-1</sup>	Age for multiparous cows at the start of the considered grazing period	

Table 10: the animal tab parameters

### 3.6 The animal tab

PaSim - Laqueuille\_int

File Run Results Mode ?

Overview Plant Soil Meteo Cut & Fert Animal Outputs Properties

Name											
Potential eating rate of lactating cows (kg/animal)								10.5	Reset		
Weight of lactating cows (kg)								400.0	Valid		
Type of animal (1 Dairy - 2 Suckler - 3 Old Module - 4 Dairy heifers - 5 Suckler heifers - 6 sheep)								3			
Calving date For dairy or suckler livestock system (d)								125			
Suckling period for suckler livestock system (d)								280			
Age of the calves exit for suckler livestock systems (d)								280			
Proportion of young suckler cows (3 or 4 years old) or primipare dairy cows in the cattle								0.66			
Calf birth Weight for suckler livestock systems (kg)								400.0			
Max potential milk production (Kg/cow/d) (first)								10.0			

0	Nanimal	Tanimal	Danimal	LWYcows	LWMcows	BCSYcows	BCSMc...	LWcalves	AGE_co...	AGE_co...	Forage...
+	5.33333E-4	141	14.0	405.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	3.5E-4	155	14.0	418.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	2.83333E-4	169	31.0	431.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	3.5E-4	200	32.0	446.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	3.83333E-4	232	4.0	458.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1	Nanimal	Tanimal	Danimal	LWYcows	LWMcows	BCSYcows	BCSMc...	LWcalves	AGE_co...	AGE_co...	Forage...
+	2.13523E-4	129	6.0	454.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	3.91459E-4	135	19.0	460.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	4.98221E-4	154	8.0	476.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	8.54093E-4	162	3.0	482.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	4.98221E-4	165	19.0	485.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

2	Nanimal	Tanimal	Danimal	LWYcows	LWMcows	BCSYcows	BCSMc...	LWcalves	AGE_co...	AGE_co...	Forage...
+	2.13523E-4	126	4.0	356.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	2.84698E-4	130	5.0	362.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	4.27046E-4	135	5.0	369.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	5.33808E-4	140	9.0	377.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	6.40569E-4	149	32.0	389.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3	Nanimal	Tanimal	Danimal	LWYcows	LWMcows	BCSYcows	BCSMc...	LWcalves	AGE_co...	AGE_co...	Forage...
+	4.62633E-4	131	14.0	609.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	5.33808E-4	145	14.0	629.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	3.55872E-4	159	6.0	647.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	3.20285E-4	165	35.0	655.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	2.4911E-4	200	10.0	695.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4	Nanimal	Tanimal	Danimal	LWYcows	LWMcows	BCSYcows	BCSMc...	LWcalves	AGE_co...	AGE_co...	Forage...
+	4.98E-4	130	70.0	388.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	4.27E-4	200	15.0	458.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	2.49E-4	215	82.0	468.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-	0.0	500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
+	0.0	500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

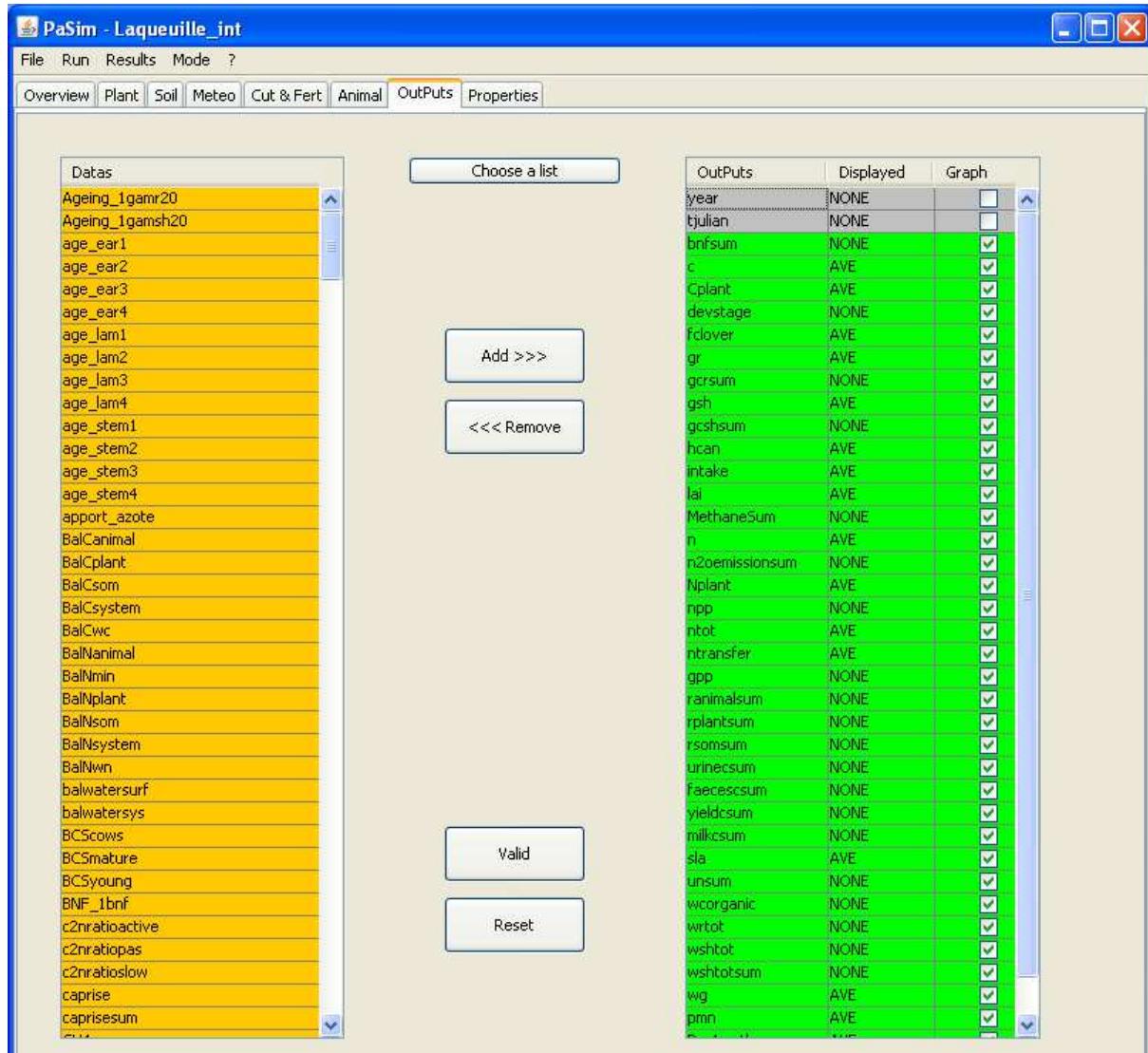
5	Nanimal	Tanimal	Danimal	LWYcows	LWMcows	BCSYcows	BCSMc...	LWcalves	AGE_co...	AGE_co...	Forage...

**Figure 13: Animal tab of the graphical interface**

Global animal properties are defined in the first array. In the following arrays (1 array per year), the user defines the animal management, he can use up to 10 lines for 10 events (+/- button to add or delete lines).



### 3.7 The outputs tab



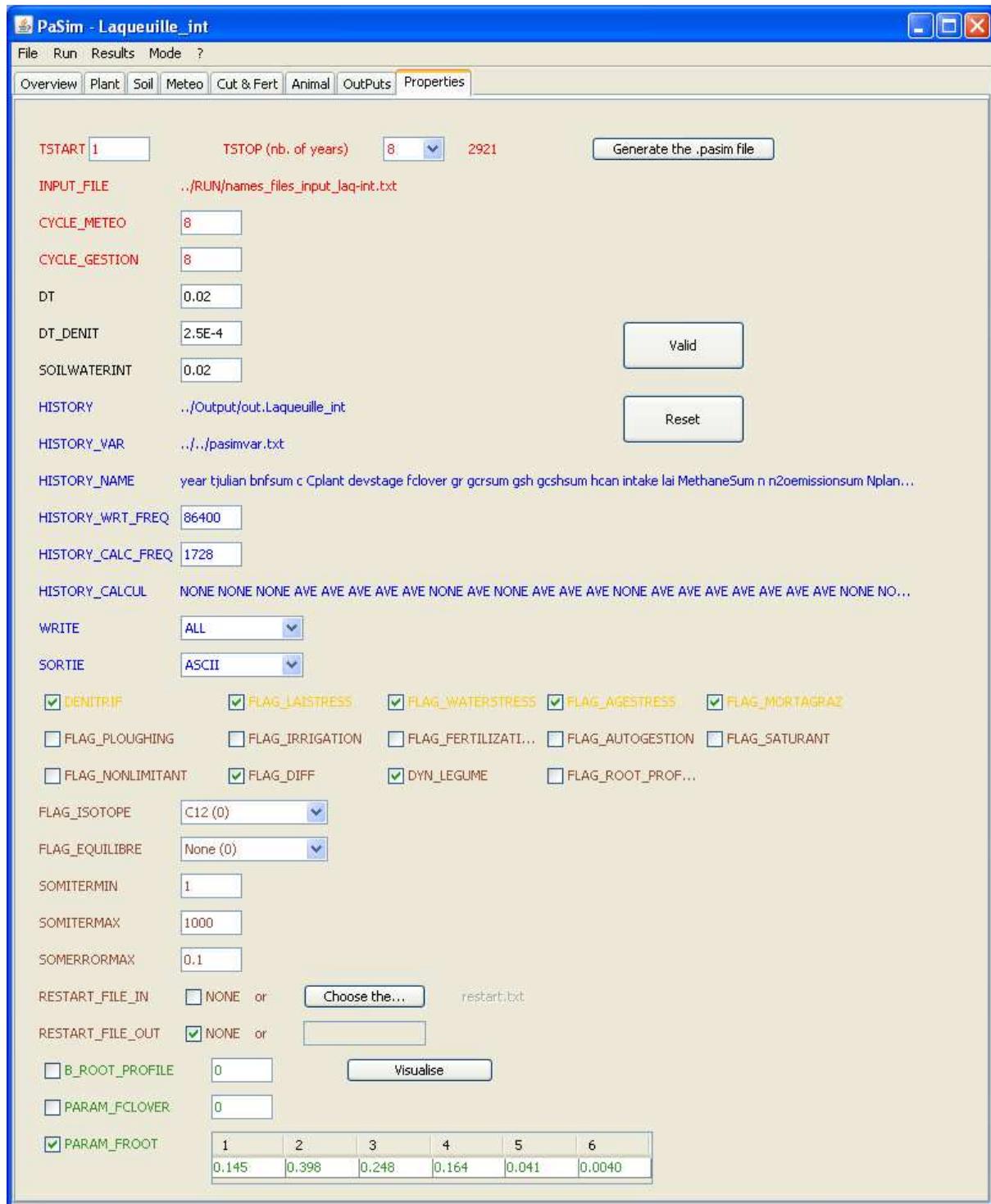
**Figure 14: Outputs tab of the graphical interface**

In this tab the user can choose all the variables he wants in output for PaSim run. He can also choose if he wants graphics of these variables or not. The annexe 3 is listing the variables.

The interface also proposed to load a pre-defined list of variables, corresponding to the most asked variables.



### 3.8 The properties tab



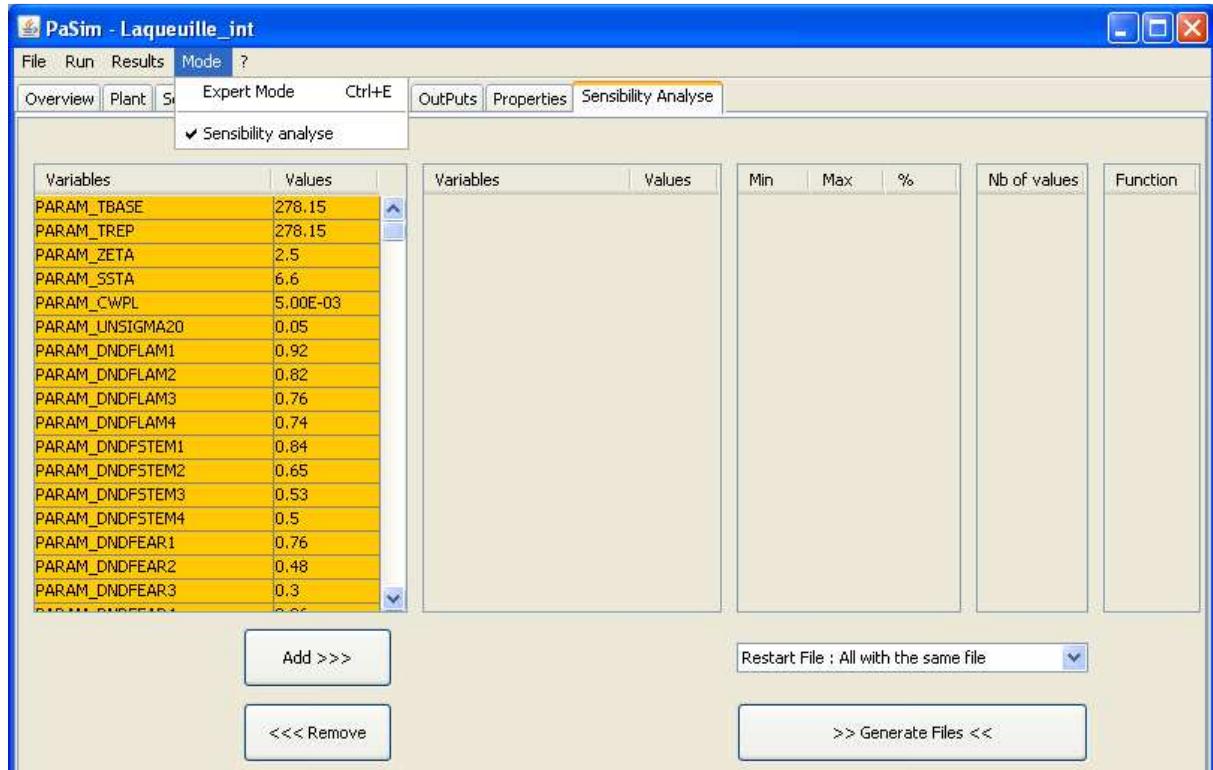
**Figure 15: Properties tab of the graphical interface**

In this interface the user can see and modify all the variables presents in the .pasim file of the grassland (cf. PASIM run file, page 22).

The user can also generate the .pasim file associate to this tab.



### 3.9 The sensibility analyse tab



**Figure 16: Sensibility tab of the graphical interface**

This tab appears only if the user wants to, and allows to generate all the needed files to perform a sensitivity analyse.

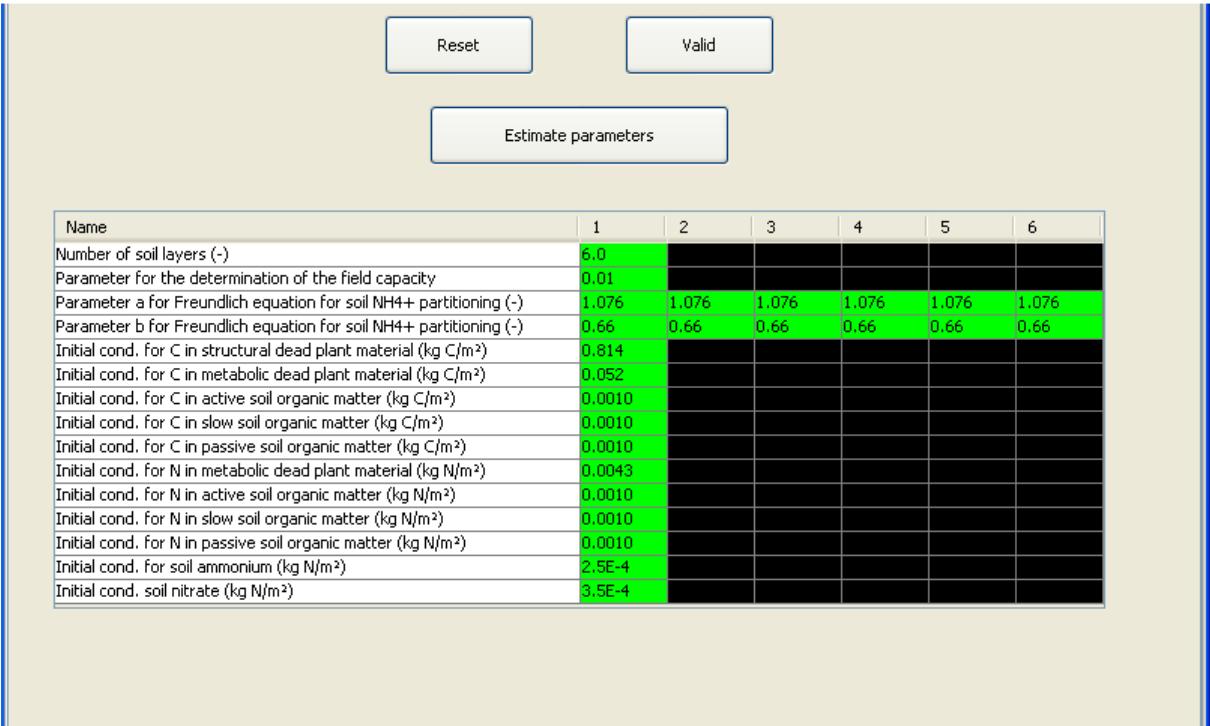
Number of soil layers	-	Soil will be highly better simulated with 6 soil layers	6.0
Parameter a for Freundlich equation for soil NH4+ partitioning	-	Does not change	1.076
Parameter b for Freundlich equation for soil NH4+ partitioning	-	Does not change	0.66
Initial cond. for C in structural dead plant material	kg C/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for C in metabolic dead plant material	kg C/m <sup>2</sup>	Prefer default value	0.814
Initial cond. for C in active soil organic matter	kg C/m <sup>2</sup>	Prefer default value	0.052
Initial cond. for C in slow soil organic matter	kg C/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for C in passive soil organic matter	kg C/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for N in metabolic dead plant material	kg N/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for N in active soil organic matter	kg N/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for N in slow soil organic matter	kg N/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for N in passive soil organic matter	kg N/m <sup>2</sup>	Prefer default value	0.001
Initial cond. for soil ammonium	kg N/m <sup>2</sup>	Prefer default value	0.00025
Initial cond. soil nitrate	kg N/m <sup>2</sup>	Prefer default value	0.00035
Initial condition for soil water content	m <sup>3</sup> / m <sup>3</sup>	Should not be higher than saturated value	

Table 11: the soil tab parameters in expert mode

### 3.10 The expert mode

The graphical interface can be used in an expert mode.

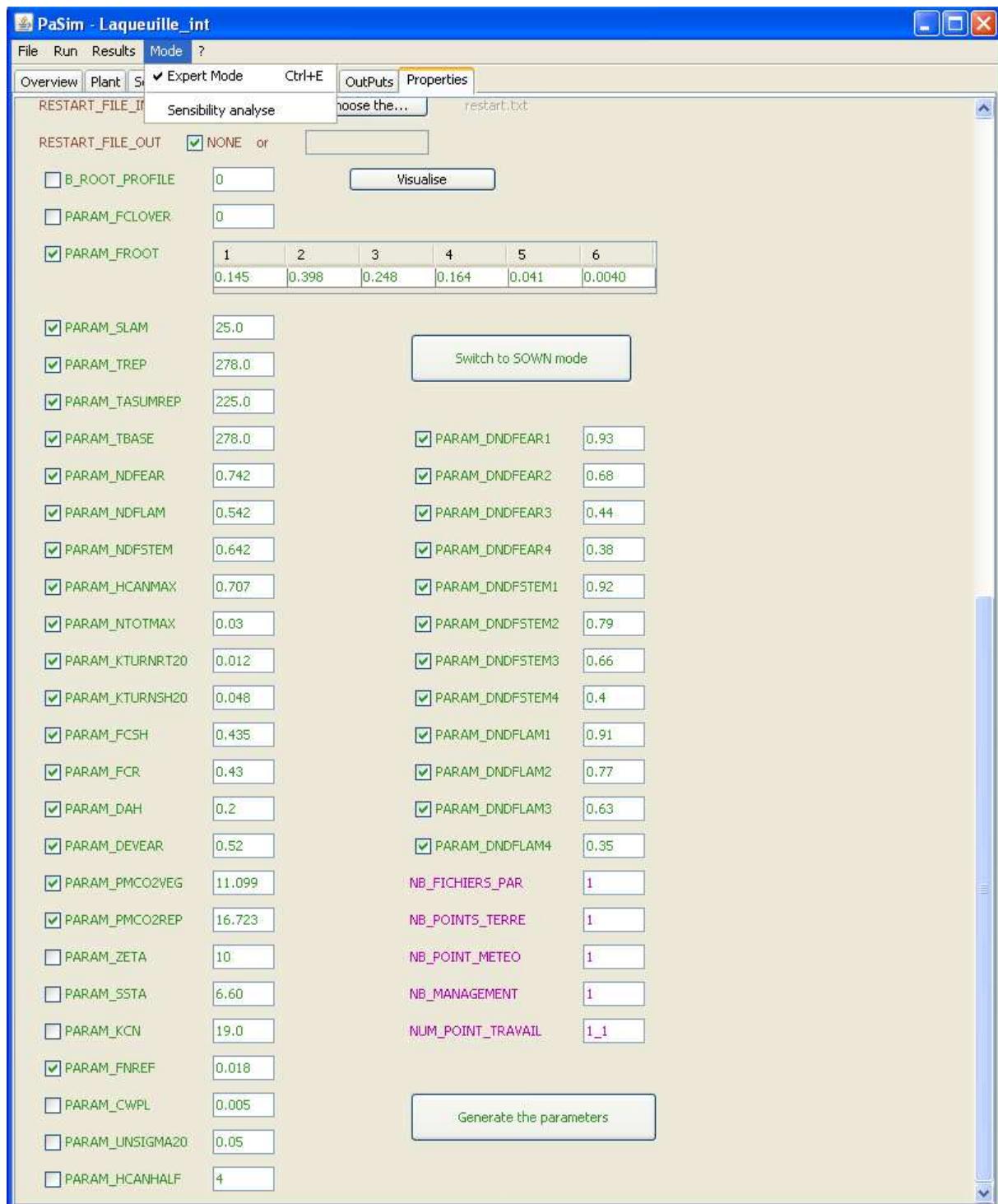
This mode allows the user to modify more parameters in the soil tab (cf. Figure 17), and in the properties tab (cf. Figure 18).



Name	1	2	3	4	5	6
Number of soil layers (-)	6.0					
Parameter for the determination of the field capacity	0.01					
Parameter a for Freundlich equation for soil NH4+ partitioning (-)	1.076	1.076	1.076	1.076	1.076	1.076
Parameter b for Freundlich equation for soil NH4+ partitioning (-)	0.66	0.66	0.66	0.66	0.66	0.66
Initial cond. for C in structural dead plant material (kg C/m <sup>2</sup> )	0.814					
Initial cond. for C in metabolic dead plant material (kg C/m <sup>2</sup> )	0.052					
Initial cond. for C in active soil organic matter (kg C/m <sup>2</sup> )	0.0010					
Initial cond. for C in slow soil organic matter (kg C/m <sup>2</sup> )	0.0010					
Initial cond. for C in passive soil organic matter (kg C/m <sup>2</sup> )	0.0010					
Initial cond. for N in metabolic dead plant material (kg N/m <sup>2</sup> )	0.0043					
Initial cond. for N in active soil organic matter (kg N/m <sup>2</sup> )	0.0010					
Initial cond. for N in slow soil organic matter (kg N/m <sup>2</sup> )	0.0010					
Initial cond. for N in passive soil organic matter (kg N/m <sup>2</sup> )	0.0010					
Initial cond. for soil ammonium (kg N/m <sup>2</sup> )	2.5E-4					
Initial cond. soil nitrate (kg N/m <sup>2</sup> )	3.5E-4					

**Figure 17: Soil tab of the graphical interface in expert mode**

The number of soil layer can't be changed.



**Figure 18: Properties tab of the graphical interface in expert mode**

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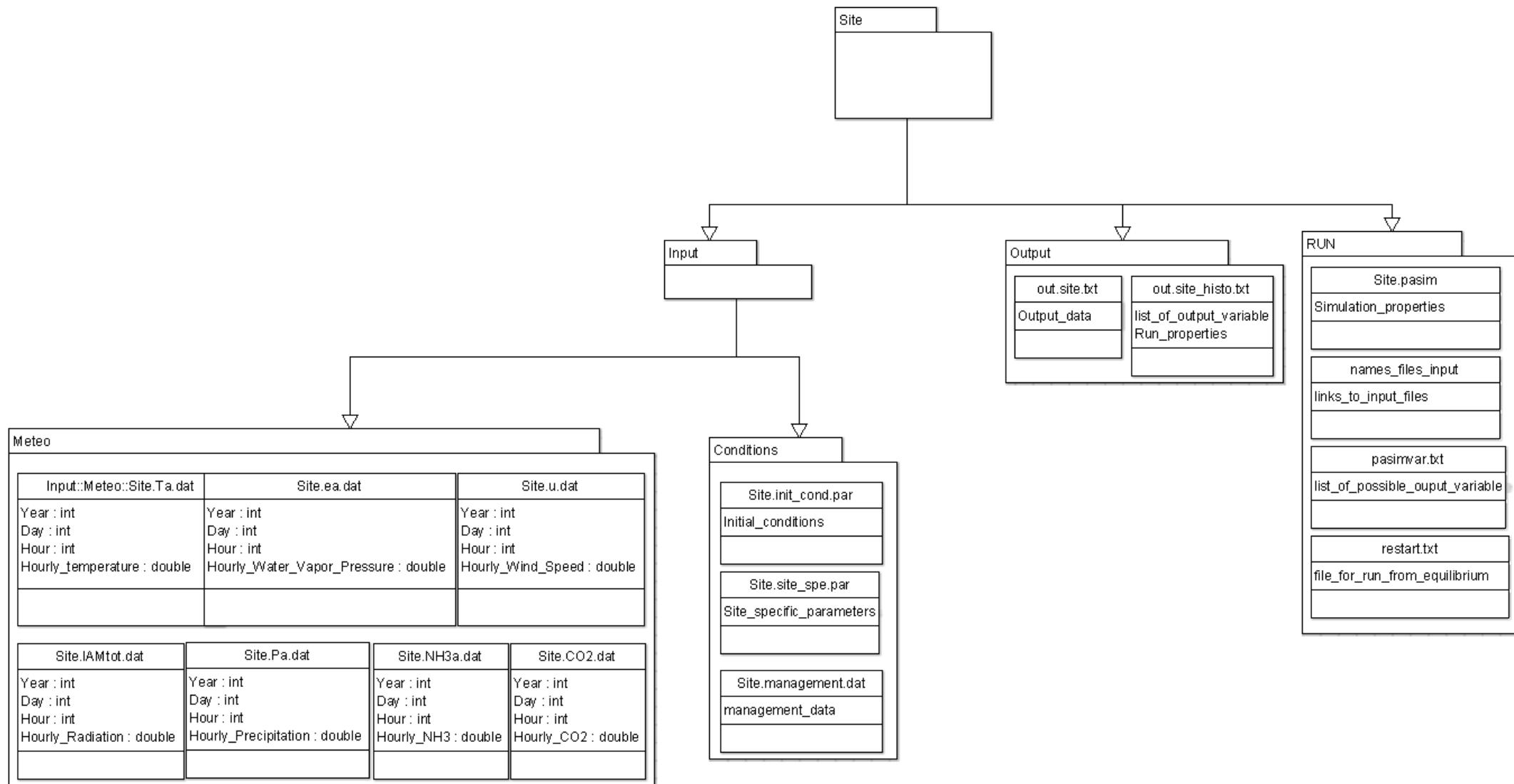
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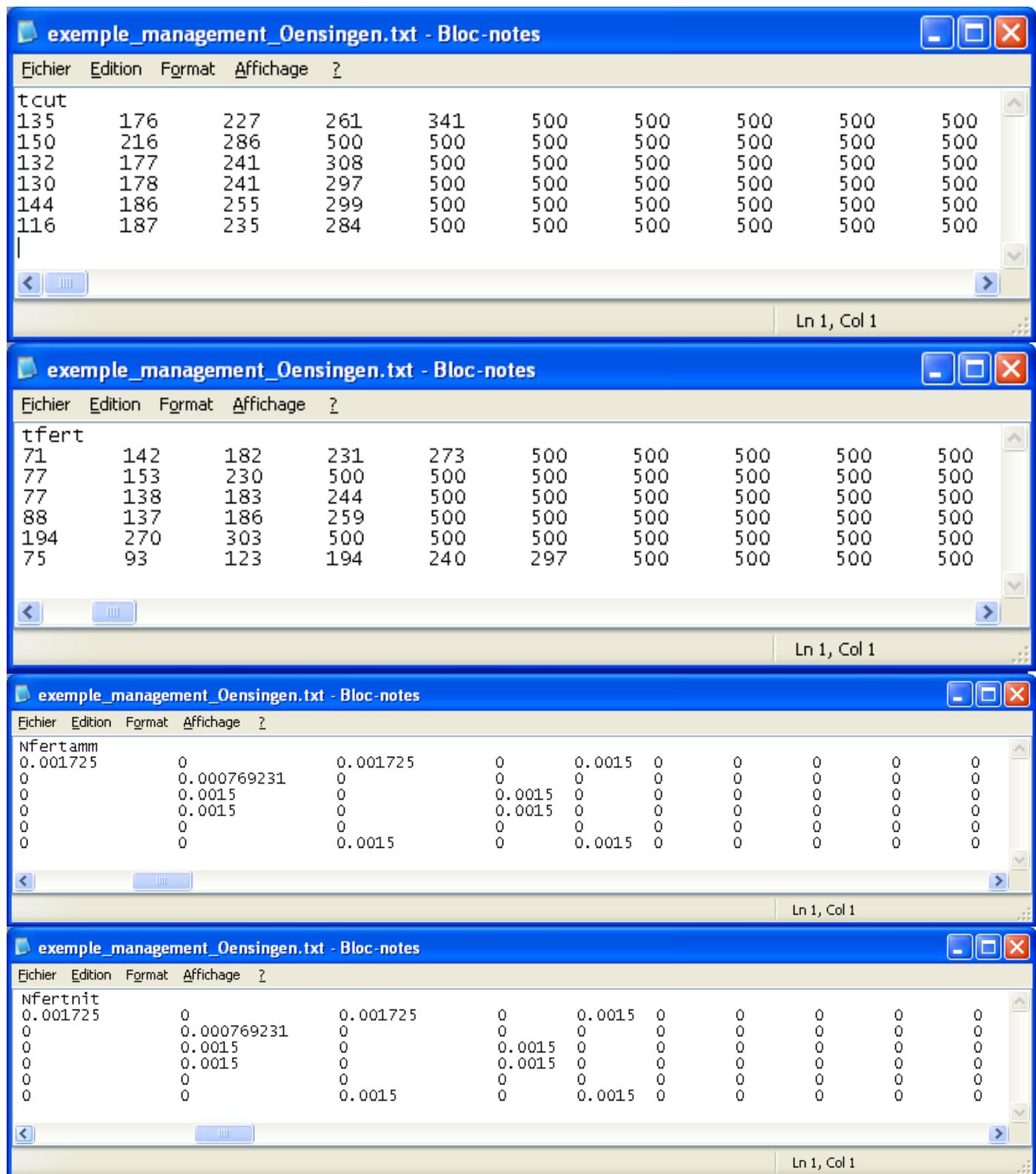
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## Annexe 1: Usual Tree Structure of PaSim

## Annexe 2: Example of management file



exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

tcut

135	176	227	261	341	500	500	500	500	500
150	216	286	500	500	500	500	500	500	500
132	177	241	308	500	500	500	500	500	500
130	178	241	297	500	500	500	500	500	500
144	186	255	299	500	500	500	500	500	500
116	187	235	284	500	500	500	500	500	500

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

tfert

71	142	182	231	273	500	500	500	500	500
77	153	230	500	500	500	500	500	500	500
77	138	183	244	500	500	500	500	500	500
88	137	186	259	500	500	500	500	500	500
194	270	303	500	500	500	500	500	500	500
75	93	123	194	240	297	500	500	500	500

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Nfertamm

0.001725	0	0.001725	0	0.0015	0	0	0	0	0
0	0.000769231	0	0	0	0	0	0	0	0
0	0.0015	0	0.0015	0	0	0	0	0	0
0	0.0015	0	0.0015	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0.0015	0	0.0015	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Nfertnnt

0.001725	0	0.001725	0	0.0015	0	0	0	0	0
0	0.000769231	0	0	0	0	0	0	0	0
0	0.0015	0	0.0015	0	0	0	0	0	0
0	0.0015	0	0.0015	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0.0015	0	0.0015	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

nanimal

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

tanimal

500	500	500	500	500	500	500	500	500	500	500
500	500	500	500	500	500	500	500	500	500	500
500	500	500	500	500	500	500	500	500	500	500
500	500	500	500	500	500	500	500	500	500	500
500	500	500	500	500	500	500	500	500	500	500
500	500	500	500	500	500	500	500	500	500	500
500	500	500	500	500	500	500	500	500	500	500

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

danimal

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Nfertvg

0	0.002486828	0	0.003227081	0	0	0	0	0	0	0
0.005353003	0	0.001896733	0	0	0	0	0	0	0	0
0.001517387	0	0.000505796	0	0	0	0	0	0	0	0
0.00311832	0	0.0035	0	0	0	0	0	0	0	0
0.00143	0.00127	0.00321	0	0	0	0	0	0	0	0
0	0.00463	0	0.00184	0	0.0030135	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

NfetKg

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

NfertMist

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Lw of young cows

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Lw of mature cows

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

BCS of young cows

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

BCS of mature cows

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Initial calf LW (at the beginning of grazing period)

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Initial age cow (Primiparous)

36	36	36	36	36	36	36	36	36	36
36	36	36	36	36	36	36	36	36	36
36	36	36	36	36	36	36	36	36	36
36	36	36	36	36	36	36	36	36	36
36	36	36	36	36	36	36	36	36	36
36	36	36	36	36	36	36	36	36	36

Ln 1, Col 1

exemple\_management\_Oensingen.txt - Bloc-notes

Fichier Edition Format Affichage ?

Initial age cow (multi)

50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50
50	50	50	50	50	50	50	50	50	50

oens.management - Bloc-notes

Fichier Edition Format Affichage ?

Forage quantity

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

## Annexe 3: The pasimvar file: list of PaSim possible outputs

475

Ageing\_1gamr20, Rate parameter for root turnover at 20°C,d-1,7  
 Ageing\_1gamsh20, Rate parameter for shoot turnover at 20°C,d-1,7  
 age\_ear1, age of biomass in the ear compartment,d,7  
 age\_ear2, age of biomass in the ear compartment,d,7  
 age\_ear3, age of biomass in the ear compartment,d,7  
 age\_ear4, age of biomass in the ear compartment,d,7  
 age\_lam1, age of biomass in the lam compartment,d,7  
 age\_lam2, age of biomass in the lam compartment,d,7  
 age\_lam3, age of biomass in the lam compartment,d,7  
 age\_lam4, age of biomass in the lam compartment,d,7  
 age\_stem1, age of biomass in the stem compartment,d,7  
 age\_stem2, age of biomass in the stem compartment,d,7  
 age\_stem3, age of biomass in the stem compartment,d,7  
 age\_stem4, age of biomass in the stem compartment,d,7  
 apport\_azote, annual fertilization,kg N m-2,7  
 BalCanimal, animal carbon balance,kg C m-2,7  
 BalCplant, plant carbon balance,kg C m-2,7  
 BalCsom, soil carbon balance,kg C m-2,7  
 BalCsystem, carbon balance of the global system (plants-soil-animals),kg C m-2,7  
 BalCwc, carbon substrate balance of plant,kg C m-2,7  
 BalNanimal, animal nitrogen balance,kg N m-2,7  
 BalNmin, nitrogen minimal balance of plant,kg N m-2,7  
 BalNplant, plant nitrogen balance,kg N m-2,7  
 BalNsom, soil nitrogen balance,kg N m-2,7  
 BalNsystem, nitrogen balance of the global system (plants-soil-animals),kg N m-2,7  
 BalNwn, nitrogen substrate balance of plant,kg N m-2,7  
 balwatersurf, surface water balance of the system,mm,7  
 balwatersys, water balance of the system,mm,7  
 BCScows, Average BCS of cows, Kg (animal)-1,7  
 BCSmature, Body score condition of mature suckler cows, -,7  
 BCSyoung, Body score condition of young suckler cows, -,7  
 BNF\_1bnf, daily biological nitrogen fixation,kg N m-2,7  
 bnfsum, biological nitrogen fixation,kg N m-2,7  
 c, carbon substrate concentration in plant,kg C (kg DM)-1,9  
 c2nradioactive, C/N ratio of active fraction of soil organic matter,kg C (kg N)-1,9  
 c2nratiospas, C/N ratio of pasive fraction of soil organic matter,kg C (kg N)-1,9  
 c2nratioslow, C/N ratio of slow fraction of soil organic matter,kg C (kg N)-1,9  
 caprise, daily capillary rise,mm d-1,7  
 caprisesum, capillary rise,mm,7  
 CH4young, CH4 produced by Young/primipare cows, (Kg C/m<sup>2</sup>\*d),7  
 CH4mature, CH4 produced by Mature/mulitpare cows, (Kg C/m<sup>2</sup>\*d),7  
 controle\_A\_S, annual carbon substrate biomass,kg C (kg DM)-1,7  
 Cplant, total (substrate and structural) plant carbon,kg C m-2,9  
 Csystem, total (plant and total organic soil) carbon in the system,kg C m-2,9  
 da, deficit in atmospheric vapour pressure,kPa,7  
 dah, main rooting deth ,m,7  
 dETR2dET0, real versus potential daily evapotranspiration,mm,7  
 dET0, daily reference evapotranspiration,mm,7  
 dETP, daily potential evapotranspiration,mm,7  
 devapo, daily soil evaporation,mm d-1,7  
 devar, Developmental stage at which ear emergence starts, -,7  
 devstage, development stage index, -,7  
 dfclover, daily variation of the legume fraction,% d-1,7  
 diffn2o\_1, diffn2o à l'interface de la première couche, ?,7  
 diffn2o\_2, diffn2o à l'interface de la seconde couche, ?,7  
 diffn2o\_3, diffn2o à l'interface de la troisième couche, ?,7  
 diffn2o\_4, diffn2o à l'interface de la quatrième couche, ?,7  
 diffn2o\_5, diffn2o à l'interface de la 5ème couche, ?,7  
 diffn2o\_6, diffn2o à l'interface de la 6ème couche, ?,7

diffn2odenit_1,	diffn2odenit à l'interface de la première couche,?,7
diffn2odenit_2,	diffn2odenit à l'interface de la seconde couche,?,7
diffn2odenit_3,	diffn2odenit à l'interface de la troisième couche,?,7
diffn2odenit_4,	diffn2odenit à l'interface de la quatrième couche,?,7
diffn2odenit_5,	diffn2odenit à l'interface de la 5ème couche,?,7
diffn2odenit_6,	diffn2odenit à l'interface de la 6ème couche,?,7
DMlcalf,	Dry matter ingested by calves, Kg (animal)-1,7
DMImature,	Dry matter ingested by mature suckler cows, Kg (animal)-1,7
DMlyoung,	Dry matter ingested by young suckler cows, Kg (animal)-1,7
DMlcyoung,	Concentrate ingested by young dairy cows, Kg (animal)-1,7
DMlcmatrue,	Concentrate ingested by mature dairy cows, Kg (animal)-1,7
DMlfyoung,	Forage ingested by young suckler cows, Kg (animal)-1,7
DMlfmature,	Forage ingested by mature suckler cows, Kg (animal)-1,7
dn2o,	variation of nitrous oxide soil pool,kg N m-2 d-1,2
dn2o_1,	dérivée de nn2o à l'interface de la première couche,?,7
dn2o_2,	dérivée de nn2o à l'interface de la seconde couche,?,7
dn2o_3,	dérivée de nn2o à l'interface de la troisième couche,?,7
dn2o_4,	dérivée de nn2o à l'interface de la quatrième couche,?,7
dn2o_5,	dérivée de nn2o à l'interface de la 5ème couche,?,7
dn2o_6,	dérivée de nn2o à l'interface de la 6ème couche,?,7
dn2onitrif_1,	dn2onitrif à l'interface de la première couche,?,7
dn2onitrif_2,	dn2onitrif à l'interface de la seconde couche,?,7
dn2onitrif_3,	dn2onitrif à l'interface de la troisième couche,?,7
dn2onitrif_4,	dn2onitrif à l'interface de la quatrième couche,?,7
dn2onitrif_5,	dn2onitrif à l'interface de la 5ème couche,?,7
dn2onitrif_6,	dn2onitrif à l'interface de la 6ème couche,?,7
DNDF_total,	fraction of digestible fibres in shoot,%,7
DNDF,	fraction of digestible fibres in total fibres,%,7
DNDFI,	amount of digestible fibres in the animal's intake (Digestible Neutral Detergent Fiber Intake),kg d-1,7
dNstruct,	daily Nitrogen variation in structural dry matter,mm d-1,7
drainage,	daily drainage,mm d-1,7
drainagesum,	drainage,mm,7
dtranspi,	daily plant transpiration,mm d-1,7
dwnapo,	daily variation of plant apoplastic substrate N pool,kgN m-2 d-1,7
dwnsym,	daily variation of plant symplastic substrate N pool,kgN m-2 d-1,7
ea,	vapour pressure at reference height z above the canopy,kPa,7
ETR2ET0,	real versus potential evapotranspiration,-,7
ET0,	reference evapotranspiration,mm,7
ETP,	potential evapotranspiration,mm,7
E_ds,	difference between saturation vapor pressure and air vapor pressure,kPa,7
E_lecslope,	energy flux associated with transpiration,W m-2,7
E_les,	latent heat flux,W m-2,7
E_leslope,	latent heat flux (taking into account slope),W m-2,7
E_leslope,	energy flux associated with soil evaporation (taking into account slope),W m-2,7
E_ts,	Température à la hauteur du couvert,?,7
evaposum,	annual soil evaporation,mm,7
evapotrans,	evapotranspiration (transpiration+evaporation), mm,7
exudation,	carbon substrate lost by exudation,kg C m-2 d-1,9
faecesc,	carbon in faeces,kg c/(m**2 d),9
faecescsum,	annual carbon in faeces,kg C m-2,9
faecesn,	nitrogen in faeces,kg C m-2 d-1,7
faecesnsum,	annual nitrogen in faeces,(kg N m-2),7
fcloss,	carbon in yield loss,kg C m-2 d-1,9
fclover,	legume (clover) fraction in canopy,kg kg-1,7
fcmetabolic,	decomposition rate of SOM metabolic pool, kg C m-2 d-1,9
fcr,	fractional C content of root structural dry matter,kg C kg-1,7
fcrecr,	C substrate input from recycling of senescing root,kg C m-2 d-1,9
fcrecsh,	C substrate input from recycling of senescing shoot,kg C m-2 d-1,9
fcrecsum,	C substrate input from recycling of senescing dry matter,kg C m-2,9
fnrecsum,	N substrate input from recycling of senescing dry matter,kg N m-2,7
fcresidue,	carbon in flow of plant residue,kg C m-2 d-1,9
fcsh,	fractional C content of shoot structural dry matter,kg C kg-1,7
flam,	fraction of shoot structural growth partitioned to the lamina, kg kg-1,7
fstem,	fraction of shoot structural growth partitioned to the stems, kg kg-1,7
fear,	fraction of shoot structural growth partitioned to the ears, kg kg-1,7
fn,	nitrogen in structural dry matter,kg N kg-1 DM,7
fn2osoilatm,	n2o exchange between the soil and the atmosphere or daily n2o emission,kg N m-2 d-1,7

fnaposym,	daily active substrate nitrogen flux from apoplast to symplast,kg N m-2 d-1,7
fnatmsum,	nitrogen deposition,kg N m-2,7
fncuticleSsum,	annual N from the leaf cuticle washed to the soil surface through precipitation,kg N m-2,7
fnh3_ns,	daily ammonia flux trough stomata,kg N m-2 d-1,7
fnh3_nsoil,	ammonia volatilization from soil,kg N/(m**2*d),7
fnh3_nsoilsum,	annual ammonia volatilization from soil,kg N m-2,7
fnh3_ntsum,	annual ammonia losses from volatilization,?,7
fnimmexusum,	immobilisation from N root exudation,kg N m-2 d-1,7
fnimmmisum,	immobilisation from N plant residue,kg N m-2 d-1,7
fnmintot,	N soil mineralization,kg N m-2 d-1,7
fnmintotsum,	annual N soil mineralization,kg N m-2,7
fnref,	parameter controlling nitrogen concentration of structural dry matter,kg N kg-1,7
fnresidue,	nitrogen in flow of plant residue,kg N m-2 d-1,7
froot,	Relative root dry matter in different soil layers,-,2
fnsympo,	daily nitrogen diffusion between apoplast and symplast,kg N m-2 d-1,7
fresidue,	Flow of plant residus,kg DM m-2?,7
ftclover,	target legume fraction,%,7
fwroot,	factor controlling the effect of soil water content on root and shoot turnover rates,%,7
gamsh_ear_1,	total (with senescence term) turnover rate of ear compartment of age 1,d-1,7
gamsh_ear_2,	total (with senescence term) turnover rate of ear compartment of age 2,d-1,7
gamsh_ear_3,	total (with senescence term) turnover rate of ear compartment of age 3,d-1,7
gamsh_ear_4,	total (with senescence term) turnover rate of ear compartment of age 4,d-1,7
gamsh_lam_1,	total (with senescence term) turnover rate of lam compartment of age 1,d-1,7
gamsh_lam_2,	total (with senescence term) turnover rate of lam compartment of age 2,d-1,7
gamsh_lam_3,	total (with senescence term) turnover rate of lam compartment of age 3,d-1,7
gamsh_lam_4,	total (with senescence term) turnover rate of lam compartment of age 4,d-1,7
gamsh_stem_1,	total (with senescence term) turnover rate of stem compartment of age 1,d-1,7
gamsh_stem_2,	total (with senescence term) turnover rate of stem compartment of age 2,d-1,7
gamsh_stem_3,	total (with senescence term) turnover rate of stem compartment of age 3,d-1,7
gamsh_stem_4,	total (with senescence term) turnover rate of stem compartment of age 4,d-1,7
gamshtot,	total senescent shoot dry matter, kg DM m-2,7
gcrsum,	annual carbon substrate in root dry matter,kg C (kg DM)-1,9
gcshsum,	annual carbon substrate in shoot dry matter,kg C (kg DM)-1,9
gmean,	mean growth rate,kg DM m-2*d,5
gpp,	gross primary productivity (GPP),kg C m-2,9
gr,	root growth rate,kg m-2 d-1,9
grazingc,	C flux associated to grazing,kg C m-2 d-1,9
grazingcstT,	structural carbon lost by grazing,kg C m-2,9
grazingcsum,	C in yearly grazed plant dry matter,kg C m-2 y-1,9
grazingear1,	biomass of ear compartment (age 1) grazed by animals,kg DM m-2,9
grazingear2,	biomass of ear compartment (age 2) grazed by animals,kg DM m-2,9
grazingear3,	biomass of ear compartment (age 3) grazed by animals,kg DM m-2,9
grazingear4,	biomass of ear compartment (age 4) grazed by animals,kg DM m-2,9
grazinglam1,	biomass of lam compartment (age 1) grazed by animals,kg DM m-2,9
grazinglam2,	biomass of lam compartment (age 2) grazed by animals,kg DM m-2,9
grazinglam3,	biomass of lam compartment (age 3) grazed by animals,kg DM m-2,9
grazinglam4,	biomass of lam compartment (age 4) grazed by animals,kg DM m-2,9
grazingnstT,	structural nitrogen lost by grazing,kg N m-2,7
grazingstem1,	biomass of stem compartment (age 1) grazed by animals,kg DM m-2,9
grazingstem2,	biomass of stem compartment (age 2) grazed by animals,kg DM m-2,9
grazingstem3,	biomass of stem compartment (age 3) grazed by animals,kg DM m-2,9
grazingstem4,	biomass of stem compartment (age 4) grazed by animals,kg DM m-2,9
grazingwc,	carbon substrate lost by grazing,kg C m-2,9
grazingwn,	nitrogen substrate lost by grazing,kg N m-2,7
gs,	soil heat flux,W m-2,7
gsh,	shoot growth rate,kg m-2 d-1,9
gsslope,	soil heat flux (taking into account slope),W m-2,7
GWP_C,	global warming potential(gwp) of carbon (from system respiration),t C/ha,9
GWP_M,	global warming potential(gwp) of methane (from animals),t C/ha,9
GWP_N,	global warming potential(gwp) of nitrogen (from denitrification),t C/ha,7
hcan,	canopy height,m,7
hcanmax,	Flowering plant height highest leaf not elongated,m,7
HumidityIndex,	ratio precipitations: potential evapotranspiration,mm,7
h_10,	threshold canopy height for light competition or umbrage effect,m,7
htot,	total sensible heat flux,W m-2,7
iatmtot,	global radiation (300-3000nm),W m-2,7
inetc,	net radiation above canopy,W m-2,7

inetcslope,	slope of the net radiation at the soil surface,?,7
inetcsum,	net radiation above the canopy,W m-2,7
inets,	net radiation at soil surface,W m-2,7
inetsslope,	slope of the net radiation above the canopy,?,7
inn,	Nitrogen Nutrition Index ,-,7
intake_animal,	daily animal intake per animal,kg DM animal-1 d-1,7
intake_animalsum,	intake per lsu,kg DM animal -1,7
intake,	daily animal intake per m2,kg DM m-2 d-1,7
intakesum,	intake per m2,kg DM m-2,7
irrigation,	daily irrigation,mm d-1,7
irrSum,	irrigation,mm,7
ishadedpar,	PAR absorbed from shaded leaves in canopy,W m-2,5
isunpar,	PAR absorbed from sunlit leaves in canopy,W m-2,5
k,	k,?,5
kplantalt,	factor controlling the effect of altitude on shoot growth,-,7
kplantdev,	factor controlling the effect of development on shoot growth,-,7
kplantsht,	factor controlling the effect of temperature on shoot growth,-,7
kt,	thermal conductivity of soil layers,w/(m**2*k),2
kturnrt,	root turnover rate including water and LAI limitations,d-1,7
kturnsh,	shoot turnover rate including water and LAI limitations,d-1,7
lai,	leaf area index (LAI), m2 leaf m-2 soil,7
le,	latent heat flux,(w/m**-2),7
leach,	daily nitrate leaching (vertical transfert) between soil layers,kg N m-2 d-1,2
leach_1,	daily nitrate leaching in the soil layer 1,kg N m-2 d-1,7
leach_2,	daily nitrate leaching in the soil layer 2,kg N m-2 d-1,7
leach_3,	daily nitrate leaching in the soil layer 3,kg N m-2 d-1,7
leach_4,	daily nitrate leaching in the soil layer 4,kg N m-2 d-1,7
leach_5,	daily nitrate leaching in the soil layer 5,kg N m-2 d-1,7
leach_6,	daily nitrate leaching in the soil layer 6,kg N m-2 d-1,7
leach_nsoil,	daily nitrate leaching in the last (the deepest) soil layer,kg N m-2 d-1,7
leachn2o,	nitrous oxide leaching,kg N m-2 d-1,2
leachsum,	nitrate leaching,kg N m-2,7
lecsstep,	extraction of water by the root integrated on a step of time,mm/step of time,2
lecs,	extraction of water by the root for all soil layers,mm,2
lesstep,	soil evaporation integrated on a step of time?,mm/step of time,7
llam1,	lamina component (age 1) of leaf area index,m2 m-2,7
llam2,	lamina component (age 2) of leaf area index,m2 m-2,7
llam3,	lamina component (age 3) of leaf area index,m2 m-2,7
llam4,	lamina component (age 4) of leaf area index,m2 m-2,7
loss,	dry matter lost by cuts,kg DM m-2,7
lossc,	carbon in dry matter lost by cuts,kg C m-2,9
losscsum,	annual carbon lost,kg c m-2,9
lossn,	nitrogen in dry matter lost by cuts,kg N m-2,7
lst1,	stem component (age 1) of leaf area index,m2 m-2,7
lst2,	stem component (age 2) of leaf area index,m2 m-2,7
lst3,	stem component (age 3) of leaf area index,m2 m-2,7
lst4,	stem component (age 4) of leaf area index,m2 m-2,7
methane,	daily methane emissions by herbivorous,kg C m-2 d-1,9
methane_ani,	daily enteric methane emissions per animal,kg C (animal)-1 d-1,9
methane_aniSum,	enteric methane emissions per animal,kg C (animal)-1,9
MethaneSum,	methan emissions by herbivorous per m2,kg C m-2,9
milk,	daily milk production,kg m-2 d-1,7
milkanimal,	daily milk production per animal,kg (animal)-1 d-1,7
milkanimalsum,	milk production per animal,kg (animal)-1,7
milkc,	carbon in milk,kg C m-2 d-1,9
milkcsum,	annual carbon in milk,kg c m-2,9
milkn,	nitrogen in milk,kg N m-2 d-1,7
milksum,	milk production,kg m-2,7
MPyoung,	milk production of young cows, kg animal-1 d-1,7
MPmature,	milk production of mature cows, kg animal-1 d-1,7
MPwyong,	potential milk production of young cows, kg animal-1 d-1,7
MPwmature,	potential milk production of mature cows, kg animal-1 d-1,7
MPposyoung,	possible milk production of dairy young cows, kg animal-1 d-1,7
MPposmature,	possible milk production of dairy mature cows, kg animal-1 d-1,7
n,	nitrogen substrate concentration in plant,kg N kg-1 DM,7
n2denitrifsum,	annual dinitrogen losses from denitrification,kg N m-2,7
n2oemissionsum,	n2O emission,kg N m-2,7

n2oleachingS,	annual nitrous oxide leaching,kg N m-2,7
namm,	ammonium-n in soil layer h,kg N m-2,2
namm_1,	N ammonium in first soil layer,kg N m-2,7
namm_2,	N ammonium in second soil layer,kg N m-2,7
namm_3,	N ammonium in third soil layer,kg N m-2,7
namm_4,	N ammonium in fourth soil layer,kg N m-2,7
namm_5,	N ammonium in fifth soil layer,kg N m-2,7
namm_6,	N ammonium in sixth soil layer,kgN m-2,7
nammsurface,	ammonium-n at the soil surface,kg N m-2,7
nammtot,	total N ammonium in soil,kg N m-2,7
nanimaltot,	stocking rate,animal m-2,7
napo,	n concentration of apoplast,kg N m-2,7
NBP,	Net Biome productivity,kg C m-2,7
ncuticle,	nh3-n auf der blattoberflaeche,kg N m-2,7
NDF_total,	fraction of fibres in shoot,%,7
NDF,	fraction of fibres in the intake,%,7
NDFear,	Fraction of fibres in ingested ears,%,7
NDFlam,	Fraction of fibres in ingested lams,%,7
NDFstem,	Fraction of fibres in ingested sheaths and stems,%,7
NEE,	Net Ecosystem Exchange, kg C/m2,9
NEByoung,	Net energy balance of young or primiparous cows,MJ,7
NEBmature,	Net energy balance of mature or multiparous cows,MJ,7
NElyoung,	Net energy intake of young or primiparous cows,MJ,7
NEImature,	Net energy intake of mature or multiparous cows,MJ,7
nel,	net energy for lactation,MJ kg-1,7
nelgrazingsum,	annual energy available for the whole cattle from grazing,MJ kg-1,7
nfertammtot,	total N ammonium fertilization (with previous year fertilization),kg N m-2,7
nfertammtotyear,	annual total N ammonium fertilization (without previous year fertilization),kg N m-2,7
nfertnittot,	total N nitrate fertilization (with previous year fertilization),kg N m-2,7
nfertnittotyear,	annual total N nitrate fertilization (without previous year fertilization),kg N m-2,7
Nfert,	Daily N fertilization optimized by the model according to INN,kg N m-2 d-1,7
NfertSum,	Cumulated N fertilization optimized by the model according to INN,kg N m-2,7
nn2o,	n2o content in soil layer h,kg N m-2,2
nn2odenit,	nitrous oxide content in the denitrification pool,kg N m-2,2
nn2ogas_1,	[N2O gaz] into the soil layer 1,?,7
nn2ogas_2,	[N2O gaz] into the soil layer 2,?,7
nn2ogas_3,	[N2O gaz] into the soil layer 3,?,7
nn2ogas_4,	[N2O gaz] into the soil layer 4,?,7
nn2ogas_5,	[N2O gaz] into the soil layer 5,?,7
nn2ogas_6,	[N2O gaz] into the soil layer 6,?,7
nnit,	nitrate-n in soil layer h,kg N m-2,2
nnit_1,	N nitrate in first soil layer,kg N m-2,7
nnit_2,	N nitrate in second soil layer,kg N m-2,7
nnit_3,	N nitrate in third soil layer,kg N m-2,7
nnit_4,	N nitrate in fourth soil layer,kg N m-2,7
nnit_5,	N nitrate in fifth soil layer,kg N m-2,7
nnit_6,	N nitrate in sixth soil layer,kgN m-2,7
nnittot,	total nitrate-n in soil,kg N m-2,7
nno2,	NO2 content in soil layer h,kgN m-2,2
Nplant,	total (substrate structural and cuticle) plant nitrogen,kg N m-2,7
npp,	net primary productivity (NPP) npp=gpp-rplant,kg C m-2,7
nppd,	daily primary net productivity,kg C m-2 d-1,7
nsym,	n concentration of symplast,kg N m-2,7
Nsystem,	Nitrogen in the global system (plant & soil),kg N m-2,7
ntot,	total (substrate and structural) nitrogen concentration per total plant dry matter,(kg N kg-1),7
ntransfer,	daily nitrogen from legume uptake,kg N /(m**2*d),7
OMD,	Digestible organic matter,%,7
pa,	daily precipitations,mm d-1,7
PAR,	PAR absorbed from leaves in canopy, MJ m-2,7
pasum,	precipitations,mm,7
Pc_1fwatpc,	factor controlling the effect of soil water content on photosynthesis and stomatal conductance,-,7
Pc_1pctl,	canopy leaf gross photosynthetic rate calculated at leaf temperature,kg C m-2 d-1,9
Pc_1pmtl,	canopy leaf gross photosynthetic rate calculated at air temperature (Pcan),g C m-2 d-1,7
phsoil,	soil ph,-,7
pmco2rep,	Light-saturated leaf photosynthetic rate for reproductive stage,micromol m-2 s-1,7
pmco2veg,	Light-saturated leaf photosynthetic rate for vegetative stage,micromol m-2 s-1,7
pmn,	factor controlling the effect of nitrogen on photosynthesis,kg**2 m-2 d-1,7

psiroot,	root potential,J kg-1 or kPa,7
raa,	aerodynamic resistance between canopy source height and reference height z,(s/m),7
raboveplantS,	total plant respiration (for shoot growth and maintenance) at steady state,kg C m-2 d-1,9
ractive,	microbial respiration for decomposition of C in active fraction of soil organic matter,kg C m-2 d-1,9
ranimal,	daily animal respiration,kg C m-2 d-1,9
ranimalsum,	annual animal respiration,kg C m-2,9
rb,	bulk-blattgrenzschichtwiderstand,s/m,7
rbelowplantS,	total plant respiration (for root growth and maintenance) at steady state,kg C m-2 d-1,9
rc,	bulk stomatal resistance the canopy,s/m,7
RECO,	Ecosystem respiration,kg C m-2,9
regcount,	counter of cuts,(-),7
rexudation,	microbial respiration of exudates from root respiration, kg C m-2 d-1,9
rgr,	growth respiration of root,kg C m-2 d-1,9
rgsh,	growth respiration of shoot,kg C m-2 d-1,9
rmetabolic,	microbial respiration for decomposition of carbon in metabolic fraction of plant residue,kg C m-2 d-1,9
rnr,	outputs of substrate C for root maintenance,kg C m-2 d-1,9
rmsh,	outputs of substrate C for shoot maintenance,kg C m-2 d-1,9
rn,	respiration associated with root n uptake,kg C m-2 d-1,9
root_density,	root_density,%,2
Roots_psiw,	weighted mean of the soil water potentials in the different soil layers,?,7
rpassive,	microbial respiration for decomposition of C in passive fraction of soil organic matter,kg C m-2 d-1,9
rplant,	daily plant respiration,kg C m-2 d-1,9
rplantsum,	plant respiration at steady state?,kg C m-2,9
rs,	soil surface resistance,s/m,7
rsa,	aerodynamic resistance between soil surface and canopy source height,(s/m),7
rslow,	microbial respiration for decomposition of C in slow fraction of soil organic matter,kg C m-2 d-1,9
rsom,	daily soil respiration,kg C m-2 d-1,9
rsomsum,	soil respiration,kg C m-2,9
Rsoil,	Soil respiration (root + OM),kg C m-2,9
Rsoilsum,	Yearly sum of soil respiration (root + OM),kg C m-2,9
rstruct,	microbial respiration for decomposition of carbon in structural fraction of plant residue,kg C m-2 d-1,9
rstructsum,	annual microbial respiration for decomposition of C in structural fraction of plant residue,kg C m-2,9
runoffsum,	runoff,mm d-1,7
rurinesum,	respiration associated with urine hydrolysis (gives ammonium N and CO2),kg C m-2,9
sla,	specific leaf area,m2 kg-1,7
slam,	Maximum specific leaf area, m2.kg-1,7
snow,	snow at the soil surface,mm,7
ssw,	water at the soil surface,mm,7
Storage_rC,	Carbon labile concentration in plant, (kg C/m-2),9
Storage_rN,	Nitrogen labile concentration in plant, (kg N/m-2),7
Storage_rrC,	Carbon stable concentration in plant, (kg C/m-2),9
Storage_rrN,	Nitrogen stable concentration in plant, (kg N/m-2),7
s_temp,	slope of the saturation vapor pressure temperature curve,kPa°C-1,7
ta,	air temperature at reference height z ,K,7
tamean1,	average air temperature 6 days before for the determination of the beginning of growth or not,K,7
tamean2,	average air temperature 5 days before for the determination of the beginning of growth or not,K,7
tamean3,	average air temperature 4 days before for the determination of the beginning of growth or not,K,7
tamean4,	average air temperature 3 days before for the determination of the beginning of growth or not,K,7
tamean5,	average air temperature 2 days before for the determination of the beginning of growth or not,K,7
tamean6,	average air temperature 1 day before for the determination of the beginning of growth or not,K,7
tameand,	mean air temperature,?,7
tasum,	air temperature sum,k*d,7
tasumrep,	Normalization factor for development Menzi 1998, °C d,7
tasumd,	cumulated units of plant development or efficient temperature sum,Kd,7
tgrowth,	date of beginning of plant growth after last cut,(d),7
thetas,	volumetric water content in soil layer h,m3 m-3,2
thetas_1,	soil water content of first soil layer,m3 m-3,7
thetas_2,	soil water content of second soil layer,m3 m-3,7
thetas_3,	soil water content of third soil layer,m3 m-3,7
thetas_4,	soil water content of fourth soil layer,m3 m-3,7
thetas_5,	soil water content of fifth soil layer,m3 m-3,7
thetas_6,	soil water content of sixth layer,m3 m-3,7
tjulian,	julian day,d,8
tleaf,	leaf temperature,K,7
transpsum,	plant transpiration,mm,7

tsoil,	soil layer temperature,k,2
tsoil_1,	soil temperature of layer 1,K,7
tsoil_2,	soil temperature of layer 2,K,7
tsoil_3,	soil temperature of layer 3,K,7
tsoil_4,	soil temperature of layer 4,K,7
tsoil_5,	soil temperature of layer 5,K,7
tsoil_6,	soil temperature of layer 6,K,7
tsoilcumm,	cumulated mean soil temperature,k,7
tss,	soil surface temperature,k,7
tss0,	value for testing tss,?,8
tss0diff,	value for testing tss,?,8
tssdiff,	value for testing tss,?,8
t_litter,	temperature of the litter,K,7
turno_ra_ear1,	senescence term which accelerates the turnover of ear compartment of age 1,d-1,7
turno_ra_ear2,	senescence term which accelerates the turnover of ear compartment of age 2,d-1,7
turno_ra_ear3,	senescence term which accelerates the turnover of ear compartment of age 3,d-1,7
turno_ra_ear4,	senescence term which accelerates the turnover of ear compartment of age 4,d-1,7
turno_ra_lam1,	senescence term which accelerates the turnover of lam compartment of age 1,d-1,7
turno_ra_lam2,	senescence term which accelerates the turnover of lam compartment of age 2,d-1,7
turno_ra_lam3,	senescence term which accelerates the turnover of lam compartment of age 3,d-1,7
turno_ra_lam4,	senescence term which accelerates the turnover of lam compartment of age 4,d-1,7
turno_ra_stm1,	senescence term which accelerates the turnover of stem compartment of age 1,d-1,7
turno_ra_stm2,	senescence term which accelerates the turnover of stem compartment of age 2,d-1,7
turno_ra_stm3,	senescence term which accelerates the turnover of stem compartment of age 3,d-1,7
turno_ra_stm4,	senescence term which accelerates the turnover of stem compartment of age 4,d-1,7
u,	wind speed at reference height z above the canopy,m/s,7
un,	daily nitrogen uptake rate by the root,kg N m-2 d-,7
unamm,	N ammonium uptake rate of the root,kg N m-2 d-,7
unnit,	N nitrate uptake rate of the root,kg N m-2 d-1,7
unsum,	nitrogen uptake rate of the root,kg N m-2,7
Un_1ntotmax,	Maximum of total nitrogen concentration in plant,kg N kg-1 DM,7
urinec,	carbon in urinate,kg C m-2 d-1,9
urinecsum,	annual carbon in urinate,kg C m-2,9
urinen,	nitrogen in urinate,kg N/(m**2*d),7
urinensum,	annual nitrogen from hydrolysis of urine excreted by grazing animals,kg N m-2,7
watersystem,	total water in the system,mm,7
wc,	substrate carbon = biomass of carbon substrate in plants,kg C m-2,9
wcactive,	carbon in active fraction of soil organic matter,kg C m-2,9
wcmetabolic,	carbon in metabolic fraction of plant residue,kg C m-2,9
wcorganic,	total organic carbon in soil,kg C m-2,9
wcpassive,	carbon in passive fraction of soil organic matter,kg C m-2,9
wcslow,	carbon in slow fraction of soil organic matter,kg C m-2,9
wcstruct,	carbon in structural fraction of plant residue,kg C m-2,9
wcstructlignin,	carbon in lignin of structural plant dry matter,kg C m-2,9
wear1,	ear component (age 1) of shoot structural dry matter,kg DM m-2,9
wear2,	ear component (age 2) of shoot structural dry matter,kg DM m-2,9
wear3,	ear component (age 3) of shoot structural dry matter,kg DM m-2,9
wear4,	ear component (age 4) of shoot structural dry matter,kg DM m-2,9
Weightcalf,	Average weight of calves,Kg,7
Weightcows,	Average weight of cows, Kg (animal)-1,7
Weightmature,	Average weight of mature cows,Kg,7
Weightyoung,	Average weight of young cows,Kg,7
wg,	plant structural dry matter,kg struct.DM m-2,7
wgn,	nitrogen in structural dry matter,kg N m-2,7
wlam1,	lamina component (age 1) of shoot structural dry matter,kg DM m-2,9
wlam2,	lamina component (age 2) of shoot structural dry matter,kg DM m-2,9
wlam3,	lamina component (age 3) of shoot structural dry matter,kg DM m-2,9
wlam4,	lamina component (age 4) of shoot structural dry matter,kg DM m-2,9
wn,	substrate nitrogen = biomass of nitrogen substrate in plant,kg N m-2,7
wnactive,	nitrogen in active fraction of soil organic matter,kg N m-2,7
wnapo,	nitrogen substrate in apoplast,kg N m-2,7
wnmetabolic,	nitrogen in metabolic fraction of plant residue,kg N m-2,7
wnorganic,	total organic nitrogen in soil,kg N m-2,7
wnpassive,	nitrogen in passive fraction of soil organic matter,kg N m-2,7
wnslow,	nitrogen in slow fraction of soil organic matter,kg N m-2,7
wnsym,	nitrogen substrate in symplast,kg N m-2,7
wr,	root structural dry matter,kg DM m-2,9

wr1,	root structural dry matter of age 1,kg DM m-2,9
wr2,	root structural dry matter of age 2,kg DM m-2,9
wr3,	root structural dry matter of age 3,kg DM m-2,9
wr4,	root structural dry matter of age 4,kg DM m-2,9
wrtot,	total (structural and substrate) root biomass,kg DM m-2,9
wsh,	shoot structural dry matter,kg DM m-2,9
wshtot,	total (structural and substrate) shoot biomass,kg DM m-2,9
wshtotsum,	yield = total (substrate + structural) shoot dry matter,kg DM m-2,9
wst1,	stem component (age 1) of shoot structural dry matter,kg m-2,9
wst2,	stem component (age 2) of shoot structural dry matter,kg m-2,9
wst3,	stem component (age 3) of shoot structural dry matter,kg m-2,9
wst4,	stem component (age 4) of shoot structural dry matter,kg m-2,9
year,	year,y,8
yieldcsum,	carbon yield,kg C m-2,9
yieldnsum,	nitrogen yield,kg N m-2,7
zsm,	maximal soil depth?,m,2

## Annexe 4: restart file of PaSim (restart.txt) (version without $^{14}\text{C}$ )

If you wish to modify the restart file manually, take care to the number of characters.

N°	PaSim	Variables	Unités
1	wcstructlignin	Carbon in the lignin of the structural dead dry matter	kg C/m <sup>2</sup>
2	nn2o 1	$\text{N}_2\text{O}$ in soil layer 1	kg N/m <sup>2</sup>
3	nn2o 2	$\text{N}_2\text{O}$ in soil layer 2	kg N/m <sup>2</sup>
4	nn2o 3	$\text{N}_2\text{O}$ in soil layer 3	kg N/m <sup>2</sup>
5	nn2o 4	$\text{N}_2\text{O}$ in soil layer 4	kg N/m <sup>2</sup>
6	nn2o 5	$\text{N}_2\text{O}$ in soil layer 5	kg N/m <sup>2</sup>
7	nn2o 6	$\text{N}_2\text{O}$ in soil layer 6	kg N/m <sup>2</sup>
8	namm 1	Ammonium in soil layer 1	kg N/m <sup>2</sup>
9	namm 2	Ammonium in soil layer 2	kg N/m <sup>2</sup>
10	namm 3	Ammonium in soil layer 3	kg N/m <sup>2</sup>
11	namm 4	Ammonium in soil layer 4	kg N/m <sup>2</sup>
12	namm 5	Ammonium in soil layer 5	kg N/m <sup>2</sup>
13	namm 6	Ammonium in soil layer 6	kg N/m <sup>2</sup>
14	nnit 1	Nitrate in soil layer 1	kg N/m <sup>2</sup>
15	nnit 2	Nitrate in soil layer 2	kg N/m <sup>2</sup>
16	nnit 3	Nitrate in soil layer 3	kg N/m <sup>2</sup>
17	nnit 4	Nitrate in soil layer 4	kg N/m <sup>2</sup>
18	nnit 5	Nitrate in soil layer 5	kg N/m <sup>2</sup>
19	nnit 6	Nitrate in soil layer 6	kg N/m <sup>2</sup>
20	nammsurface	ammonium in soil surface layer	kg N/m <sup>2</sup>
21	wcactive	Carbon in active fraction of plant residue	kg C/m <sup>2</sup>
22	wnactive	Nitrogen in active fraction of plant residue	kg N/m <sup>2</sup>
23	wcstruct	Carbon in structural fraction of plant residue	kg C/m <sup>2</sup>
24	ncuticle	Nitrogen in leaf cuticle	kg N/m <sup>2</sup>
25	wcmetabolic	Carbon in metabolic fraction of plant residue	kg N/m <sup>2</sup>
26	wnmetabolic	Nitrogen in metabolic fraction of plant residue	kg C/m <sup>2</sup>
27	wcslow	Carbon in slow fraction of plant residue	kg C/m <sup>2</sup>
28	wnslow	Nitrogen in slow fraction of plant residue	kg N/m <sup>2</sup>
29	wcpassive	Carbon in passive fraction of plant residue	kg C/m <sup>2</sup>
30	wnpassive	Nitrogen in passive fraction of plant residue	kg N/m <sup>2</sup>
31	wc	Carbon substrate in plant	kg C/m <sup>2</sup>
32	wnapo	biomass of nitrogen substrate in apoplast	kg N/m <sup>2</sup>
33	wnsym	biomass of nitrogen substrate in symplast	kg N/m <sup>2</sup>
34	wgn	Nitrogen in structural dry matter	kg N/m <sup>2</sup>
35	wlam 1	lamina shoot structural dry matter in first age component	kg/m <sup>2</sup>
36	wlam 2	lamina shoot structural dry matter in second age component	kg/m <sup>2</sup>
37	wlam 3	lamina shoot structural dry matter in third age component	kg/m <sup>2</sup>
38	wlam 4	lamina shoot structural dry matter in fourth age component	kg/m <sup>2</sup>
39	wear 1	ear shoot structural dry matter in first age component	kg/m <sup>2</sup>
40	wear 2	ear shoot structural dry matter in second age component	kg/m <sup>2</sup>
41	wear 3	ear shoot structural dry matter in third age component	kg/m <sup>2</sup>
42	wear 4	ear shoot structural dry matter in fourth age component	kg/m <sup>2</sup>
43	wst 1	stem shoot structural dry matter in first age component	kg/m <sup>2</sup>
44	wst 2	stem shoot structural dry matter in second age component	kg/m <sup>2</sup>
45	wst 3	stem shoot structural dry matter in third age component	kg/m <sup>2</sup>

46	wst 4	stem shoot structural dry matter in fourth age component	kg/m <sup>2</sup>
47	llam 1	lamina leaf area index in first age component	m <sup>2</sup> /m <sup>2</sup>
48	llam 2	lamina leaf area index in second age component	m <sup>2</sup> /m <sup>2</sup>
49	llam 3	lamina leaf area index in third age component	m <sup>2</sup> /m <sup>2</sup>
50	llam 4	lamina leaf area index in fourth age component	m <sup>2</sup> /m <sup>2</sup>
51	lst 1	stem leaf area index in first age component	m <sup>2</sup> /m <sup>2</sup>
52	lst 2	stem leaf area index in second age component	m <sup>2</sup> /m <sup>2</sup>
53	lst 3	stem leaf area index in third age component	m <sup>2</sup> /m <sup>2</sup>
54	lst 4	stem leaf area index in fourth age component	m <sup>2</sup> /m <sup>2</sup>
55	tsoil 1	Temperature in soil layer 1	K
56	tsoil 2	Temperature in soil layer 2	K
57	tsoil 3	Temperature in soil layer 3	K
58	tsoil 4	Temperature in soil layer 4	K
59	tsoil 5	Temperature in soil layer 5	K
60	tsoil 6	Temperature in soil layer 6	K
61	ssw	Soil surface liquid water	mm
62	snow	Snow cover	mm
63	thetas 1	Volumetric water content in soil layer 1	m <sup>3</sup> /m <sup>3</sup>
64	thetas 2	Volumetric water content in soil layer 2	m <sup>3</sup> /m <sup>3</sup>
65	thetas 3	Volumetric water content in soil layer 3	m <sup>3</sup> /m <sup>3</sup>
66	thetas 4	Volumetric water content in soil layer 4	m <sup>3</sup> /m <sup>3</sup>
67	thetas 5	Volumetric water content in soil layer 5	m <sup>3</sup> /m <sup>3</sup>
68	thetas 6	Volumetric water content in soil layer 6	m <sup>3</sup> /m <sup>3</sup>
69	nfertammundissolved	Ammonium from mineral fertilisation undissolved	kg N/m <sup>2</sup>
70	nfertnitundissolved	Nitrate from mineral fertilisation undissolved	kg N/m <sup>2</sup>
71	nno2 1	NO <sub>2</sub> in soil layer 1	kg N/m <sup>2</sup>
72	nno2 2	NO <sub>2</sub> in soil layer 2	kg N/m <sup>2</sup>
73	nno2 3	NO <sub>2</sub> in soil layer 3	kg N/m <sup>2</sup>
74	nno2 4	NO <sub>2</sub> in soil layer 4	kg N/m <sup>2</sup>
75	nno2 5	NO <sub>2</sub> in soil layer 5	kg N/m <sup>2</sup>
76	nno2 6	NO <sub>2</sub> in soil layer 6	kg N/m <sup>2</sup>
77	nn2odenit 1	N <sub>2</sub> O content in the denitrification pool of soil layer 1	kg N/m <sup>2</sup>
78	nn2odenit 2	N <sub>2</sub> O content in the denitrification pool of soil layer 2	kg N/m <sup>2</sup>
79	nn2odenit 3	N <sub>2</sub> O content in the denitrification pool of soil layer 3	kg N/m <sup>2</sup>
80	nn2odenit 4	N <sub>2</sub> O content in the denitrification pool of soil layer 4	kg N/m <sup>2</sup>
81	nn2odenit 5	N <sub>2</sub> O content in the denitrification pool of soil layer 5	kg N/m <sup>2</sup>
82	nn2odenit 6	N <sub>2</sub> O content in the denitrification pool of soil layer 6	kg N/m <sup>2</sup>
83	snowfallsum	Yearly sum of snow fall	mm
84	lessum	Sum of soil evaporation	mm
85	lecsu	Sum of plant transpiration	mm
86	freezingsum	Frozen water	mm
87	snowmeltsu	Slush	mm
88	rainsum	Yearly sum of rain fall	mm
89		Does not contain anything anymore	
90	snowfallsumprev	Yearly sum of snow fall from previous time step	mm
91	lessumprev	Sum of soil evaporation from previous time step	mm
92	freezingsumprev	Frozen water at previous time step	mm
93	snowmeltsumprev	Slush at previous time	mm
94	rainsumprev	Yearly sum of rain fall at previous time step	mm
95		Does not contain anything anymore	
96	wr1	root structural dry matter of age 1	Kg /m <sup>2</sup>
97	wr2	root structural dry matter of age 2	Kg /m <sup>2</sup>
98	wr3	root structural dry matter of age 3	Kg /m <sup>2</sup>
99	wr4	root structural dry matter of age 4	Kg /m <sup>2</sup>

100	regcount	counter for number of regrowths	-
101	devstage	Development stage	-
102	tamean1	Average air temperature 6 days before	K
103	tamean2	Average air temperature 5 days before	K
104	tamean3	Average air temperature 4 days before	K
105	tamean4	Average air temperature 3 days before	K
106	tamean5	Average air temperature 2 days before	K
107	tamean6	Average air temperature 1 day before	K
108	tameand	Average air temperature	K
109	tacumm	Sum of daily average temperature	K
110	tacummprev	Sum of daily average temperature for previous day	K
111	tasumd	Sum of efficient temperature	K.day
112	tcut0	Julian day for first cut	day
113	tayearsum	Yearly air sum temperature	K
114	hsteadystate	Number of meteo cycle, when searching for equilibrium	-
115	nanimaltot	Stocking rate	animal/m <sup>2</sup>
116	nfertammtot	Total ammonium fertilisation (with previous year)	Kg N/m <sup>2</sup>
117	nfertrittot	Total nitrate fertilisation (with previous year)	Kg N/m <sup>2</sup>
118	fertcount	Counter for fertilisation application	-
119	gmean 1	Average growth rate during regrowth for plant layer 1	kg/m <sup>2</sup> d
120	gmean 2	Average growth rate during regrowth for plant layer 2	kg/m <sup>2</sup> d
121	gmean 3	Average growth rate during regrowth for plant layer 3	kg/m <sup>2</sup> d
122	gmean 4	Average growth rate during regrowth for plant layer 4	kg/m <sup>2</sup> d
123	gmean 5	Average growth rate during regrowth for plant layer 5	kg/m <sup>2</sup> d
124	gmean 6	Average growth rate during regrowth for plant layer 6	kg/m <sup>2</sup> d
125	gmean 7	Average growth rate during regrowth for plant layer 7	kg/m <sup>2</sup> d
126	gmean 8	Average growth rate during regrowth for plant layer 8	kg/m <sup>2</sup> d
127	gmean 9	Average growth rate during regrowth for plant layer 9	kg/m <sup>2</sup> d
128	gmean 10	Average growth rate during regrowth for plant layer 10	kg/m <sup>2</sup> d
129	nfertammundissolved_inter	Total ammonium dissolved from first time step	Kg N/m <sup>2</sup>
130	nfertritundissolved_inter	Total nitrate dissolved from first time step	Kg N/m <sup>2</sup>
131	kt 1	Thermal conductivity of layer 1 (??? Intérêt)	W/m/K
132	kt 2	Thermal conductivity of layer 2	W/m/K
133	kt 3	Thermal conductivity of layer 3	W/m/K
134	kt 4	Thermal conductivity of layer 4	W/m/K
135	kt 5	Thermal conductivity of layer 5	W/m/K
136	kt 6	Thermal conductivity of layer 6	W/m/K
137	tsoilbm	Average temperature of lower boundary layer	K
138	lecs 1	Water extracted by the root for the layer 1	mm
139	lecs 2	Water extracted by the root for the layer 2	mm
140	lecs 3	Water extracted by the root for the layer 3	mm
141	lecs 4	Water extracted by the root for the layer 4	mm
142	lecs 5	Water extracted by the root for the layer 5	mm
143	lecs 6	Water extracted by the root for the layer 6	mm
144	Storage_rC	Carbon labile concentration in plant	kg C/m <sup>2</sup>
145	Storage_rrC	Carbon stable concentration in plant	kg C/m <sup>2</sup>
146	Storage_rN	Nitrogen labile concentration in plant	kg N/m <sup>2</sup>
147	Storage_rrN	Nitrogen stable concentration in plant	kg N/m <sup>2</sup>

## Annexe 5: restart file of PaSim (restart.txt) (<sup>14</sup>C version)

If you wish to modify the restart file manually, take care to the number of characters.

N°	PaSim	Variables	Unités
1	wcstructlignin	Carbon in the lignin of the structural dead dry matter	kg C/m <sup>2</sup>
2	Wcstructlignin_CO2	C14 or C13 fraction in carbon in the lignin of the structural dead dry matter	Bq/kg
3	nn2o 1	N <sub>2</sub> O in soil layer 1	kg N/m <sup>2</sup>
4	nn2o 2	N <sub>2</sub> O in soil layer 2	kg N/m <sup>2</sup>
5	nn2o 3	N <sub>2</sub> O in soil layer 3	kg N/m <sup>2</sup>
6	nn2o 4	N <sub>2</sub> O in soil layer 4	kg N/m <sup>2</sup>
7	nn2o 5	N <sub>2</sub> O in soil layer 5	kg N/m <sup>2</sup>
8	nn2o 6	N <sub>2</sub> O in soil layer 6	kg N/m <sup>2</sup>
9	namm 1	Ammonium in soil layer 1	kg N/m <sup>2</sup>
10	namm 2	Ammonium in soil layer 2	kg N/m <sup>2</sup>
11	namm 3	Ammonium in soil layer 3	kg N/m <sup>2</sup>
12	namm 4	Ammonium in soil layer 4	kg N/m <sup>2</sup>
13	namm 5	Ammonium in soil layer 5	kg N/m <sup>2</sup>
14	namm 6	Ammonium in soil layer 6	kg N/m <sup>2</sup>
15	nnit 1	Nitrate in soil layer 1	kg N/m <sup>2</sup>
16	nnit 2	Nitrate in soil layer 2	kg N/m <sup>2</sup>
17	nnit 3	Nitrate in soil layer 3	kg N/m <sup>2</sup>
18	nnit 4	Nitrate in soil layer 4	kg N/m <sup>2</sup>
19	nnit 5	Nitrate in soil layer 5	kg N/m <sup>2</sup>
20	nnit 6	Nitrate in soil layer 6	kg N/m <sup>2</sup>
21	nammsurface	ammonium in soil surface layer	kg N/m <sup>2</sup>
22	wcactive	Carbon in active fraction of plant residue	kg C/m <sup>2</sup>
23	wcactive_CO2	C14 or C13 fraction in carbon in active fraction of plant residue	Bq/kg
24	wnactive	Nitrogen in active fraction of plant residue	kg N/m <sup>2</sup>
25	wcstruct	Carbon in structural fraction of plant residue	kg C/m <sup>2</sup>
26	wcstruct_CO2	C14 or C13 fraction in carbon in structural fraction of plant residue	Bq/kg
27	ncuticle	Nitrogen in leaf cuticle	kg N/m <sup>2</sup>
28	wcmetabolic	Carbon in metabolic fraction of plant residue	kg N/m <sup>2</sup>
29	wcmetabolic_CO2	C14 or C13 fraction in Carbon in metabolic fraction of plant residue	Bq/kg
30	wnmetabolic	Nitrogen in metabolic fraction of plant residue	kg C/m <sup>2</sup>
31	wcslow	Carbon in slow fraction of plant residue	kg C/m <sup>2</sup>
32	wcslow_CO2	C14 or C13 fraction in Carbon in slow fraction of plant residue	Bq/kg
33	wnslow	Nitrogen in slow fraction of plant residue	kg N/m <sup>2</sup>
34	wcpassive	Carbon in passive fraction of plant residue	kg C/m <sup>2</sup>
35	wcpassive_CO2	C14 or C13 fraction in Carbon in passive fraction of plant residue	Bq/kg
36	wnpassive	Nitrogen in passive fraction of plant residue	kg N/m <sup>2</sup>
37	wc	Carbon substrate in plant	kg C/m <sup>2</sup>
38	wc_C14	C14 or C13 fraction in Carbon substrate in plant	Bq/kg
39	wnapo	biomass of nitrogen substrate in apoplast	kg N/m <sup>2</sup>
40	wnsym	biomass of nitrogen substrate in symplast	kg N/m <sup>2</sup>
41	wgn	Nitrogen in structural dry matter	kg N/m <sup>2</sup>
42	wlam 1	lamina shoot structural dry matter in first age component	kg/m <sup>2</sup>

43	wlam 1_C14	C14 or C13 fraction in lamina shoot structural dry matter in first age component	Bq/kg
44	wlam 2	lamina shoot structural dry matter in second age component	kg/m <sup>2</sup>
45	wlam 2_C14	C14 or C13 fraction in lamina shoot structural dry matter in second age component	Bq/kg
46	wlam 3	lamina shoot structural dry matter in third age component	kg/m <sup>2</sup>
47	wlam 3_C14	C14 or C13 fraction in lamina shoot structural dry matter in third age component	Bq/kg
48	wlam 4	lamina shoot structural dry matter in fourth age component	kg/m <sup>2</sup>
49	wlam 4_C14	C14 or C13 fraction in lamina shoot structural dry matter in fourth age component	Bq/kg
50	wear 1	ear shoot structural dry matter in first age component	kg/m <sup>2</sup>
51	wear 1_C14	C14 or C13 fraction in ear shoot structural dry matter in first age component	Bq/kg
52	wear 2	ear shoot structural dry matter in second age component	kg/m <sup>2</sup>
53	wear 2_C14	C14 or C13 fraction in ear shoot structural dry matter in second age component	Bq/kg
54	wear 3	ear shoot structural dry matter in third age component	kg/m <sup>2</sup>
55	wear 3_C14	C14 or C13 fraction in ear shoot structural dry matter in third age component	Bq/kg
56	wear 4	ear shoot structural dry matter in fourth age component	kg/m <sup>2</sup>
57	wear 4_C14	C14 or C13 fraction in ear shoot structural dry matter in fourth age component	Bq/kg
58	wst 1	stem shoot structural dry matter in first age component	kg/m <sup>2</sup>
59	wst 1_C14	C14 or C13 fraction in stem shoot structural dry matter in first age component	Bq/kg
60	wst 2	stem shoot structural dry matter in second age component	kg/m <sup>2</sup>
61	wst 2_C14	C14 or C13 fraction in stem shoot structural dry matter in second age component	Bq/kg
62	wst 3	stem shoot structural dry matter in third age component	kg/m <sup>2</sup>
63	wst 3_C14	C14 or C13 fraction in stem shoot structural dry matter in third age component	Bq/kg
64	wst 4	stem shoot structural dry matter in fourth age component	kg/m <sup>2</sup>
65	wst 4_C14	C14 or C13 fraction in stem shoot structural dry matter in fourth age component	Bq/kg
66	llam 1	lamina leaf area index in first age component	m <sup>2</sup> /m <sup>2</sup>
67	llam 2	lamina leaf area index in second age component	m <sup>2</sup> /m <sup>2</sup>
68	llam 3	lamina leaf area index in third age component	m <sup>2</sup> /m <sup>2</sup>
69	llam 4	lamina leaf area index in fourth age component	m <sup>2</sup> /m <sup>2</sup>
70	lst 1	stem leaf area index in first age component	m <sup>2</sup> /m <sup>2</sup>
71	lst 2	stem leaf area index in second age component	m <sup>2</sup> /m <sup>2</sup>
72	lst 3	stem leaf area index in third age component	m <sup>2</sup> /m <sup>2</sup>
73	lst 4	stem leaf area index in fourth age component	m <sup>2</sup> /m <sup>2</sup>
74	tsoil 1	Temperature in soil layer 1	K
75	tsoil 2	Temperature in soil layer 2	K
76	tsoil 3	Temperature in soil layer 3	K
77	tsoil 4	Temperature in soil layer 4	K
78	tsoil 5	Temperature in soil layer 5	K
79	tsoil 6	Temperature in soil layer 6	K
80	ssw	Soil surface liquid water	mm
81	snow	Snow cover	mm
82	thetas 1	Volumetric water content in soil layer 1	m <sup>3</sup> /m <sup>3</sup>
83	thetas 2	Volumetric water content in soil layer 2	m <sup>3</sup> /m <sup>3</sup>
84	thetas 3	Volumetric water content in soil layer 3	m <sup>3</sup> /m <sup>3</sup>
85	thetas 4	Volumetric water content in soil layer 4	m <sup>3</sup> /m <sup>3</sup>
86	thetas 5	Volumetric water content in soil layer 5	m <sup>3</sup> /m <sup>3</sup>
87	thetas 6	Volumetric water content in soil layer 6	m <sup>3</sup> /m <sup>3</sup>

88	nfertammundissolved	Ammonium from mineral fertilisation undissolved	kg N/m <sup>2</sup>
89	nfertnitundissolved	Nitrate from mineral fertilisation undissolved	kg N/m <sup>2</sup>
90	nno2 1	NO <sub>2</sub> in soil layer 1	kg N/m <sup>2</sup>
91	nno2 2	NO <sub>2</sub> in soil layer 2	kg N/m <sup>2</sup>
92	nno2 3	NO <sub>2</sub> in soil layer 3	kg N/m <sup>2</sup>
93	nno2 4	NO <sub>2</sub> in soil layer 4	kg N/m <sup>2</sup>
94	nno2 5	NO <sub>2</sub> in soil layer 5	kg N/m <sup>2</sup>
95	nno2 6	NO <sub>2</sub> in soil layer 6	kg N/m <sup>2</sup>
96	nn2odenit 1	N <sub>2</sub> O content in the denitrification pool of soil layer 1	kg N/m <sup>2</sup>
97	nn2odenit 2	N <sub>2</sub> O content in the denitrification pool of soil layer 2	kg N/m <sup>2</sup>
98	nn2odenit 3	N <sub>2</sub> O content in the denitrification pool of soil layer 3	kg N/m <sup>2</sup>
99	nn2odenit 4	N <sub>2</sub> O content in the denitrification pool of soil layer 4	kg N/m <sup>2</sup>
100	nn2odenit 5	N <sub>2</sub> O content in the denitrification pool of soil layer 5	kg N/m <sup>2</sup>
101	nn2odenit 6	N <sub>2</sub> O content in the denitrification pool of soil layer 6	kg N/m <sup>2</sup>
102	snowfallsum	Yearly sum of snow fall	mm
103	lessum	Sum of soil evaporation	mm
104	lecsu	Sum of plant transpiration	mm
105	freezingsum	Frozen water	mm
106	snowmeltsu	Slush	mm
107	rainsum	Yearly sum of rain fall	mm
108		Does not contain anything anymore	
109	snowfallsumprev	Yearly sum of snow fall from previous time step	mm
110	lessumprev	Sum of soil evaporation from previous time step	mm
111	freezingsumprev	Frozen water at previous time step	mm
112	snowmeltsumprev	Slush at previous time	mm
113	rainsumprev	Yearly sum of rain fall at previous time step	mm
114		Does not contain anything anymore	
115	wr1	root structural dry matter of age 1	Kg /m <sup>2</sup>
116	wr1_C14	C14 or C13 quantity in root structural dry matter of age 1	Bq /Kg
117	wr2	root structural dry matter of age 2	Kg /m <sup>2</sup>
118	wr2_C14	C14 or C13 quantity in root structural dry matter of age 2	Bq /Kg
119	wr3	root structural dry matter of age 3	Kg /m <sup>2</sup>
120	wr3_C14	C14 or C13 quantity in root structural dry matter of age 3	Bq /Kg
121	wr4	root structural dry matter of age 4	Kg /m <sup>2</sup>
122	wr4_C14	C14 or C13 quantity in root structural dry matter of age 4	Bq /Kg
123	regcount	counter for number of regrowths	-
124	devstage	Development stage	-
125	tamean1	Average air temperature 6 days before	K
126	tamean2	Average air temperature 5 days before	K
127	tamean3	Average air temperature 4 days before	K
128	tamean4	Average air temperature 3 days before	K
129	tamean5	Average air temperature 2 days before	K
130	tamean6	Average air temperature 1 day before	K
131	tameand	Average air temperature	K
132	tacumm	Sum of daily average temperature	K
133	tacummprev	Sum of daily average temperature for previous day	K
134	tasumd	Sum of efficient temperature	K.day
135	tcut0	Julian day for first cut	day
136	tayearsum	Yearly air sum temperature	K
137	hsteadystate	Number of meteo cycle, when searching for equilibrium	-
138	nanimaltot	Stocking rate	animal/m <sup>2</sup>
139	nfertammtot	Total ammonium fertilisation (with previous year)	Kg N/m <sup>2</sup>
140	nfertnittot	Total nitrate fertilisation (with previous year)	Kg N/m <sup>2</sup>
141	fertcount	Counter for fertilisation application	-

142	gmean 1	Average growth rate during regrowth for plant layer 1	kg/m <sup>2</sup> d
143	gmean 2	Average growth rate during regrowth for plant layer 2	kg/m <sup>2</sup> d
144	gmean 3	Average growth rate during regrowth for plant layer 3	kg/m <sup>2</sup> d
145	gmean 4	Average growth rate during regrowth for plant layer 4	kg/m <sup>2</sup> d
146	gmean 5	Average growth rate during regrowth for plant layer 5	kg/m <sup>2</sup> d
147	gmean 6	Average growth rate during regrowth for plant layer 6	kg/m <sup>2</sup> d
148	gmean 7	Average growth rate during regrowth for plant layer 7	kg/m <sup>2</sup> d
149	gmean 8	Average growth rate during regrowth for plant layer 8	kg/m <sup>2</sup> d
150	gmean 9	Average growth rate during regrowth for plant layer 9	kg/m <sup>2</sup> d
151	gmean 10	Average growth rate during regrowth for plant layer 10	kg/m <sup>2</sup> d
152	nfertammundissolved_inter	Total ammonium dissolved from first time step	Kg N/m <sup>2</sup>
153	nfertnitundissolved_inter	Total nitrate dissolved from first time step	Kg N/m <sup>2</sup>
154	kt 1	Thermal conductivity of layer 1 (??? Intérêt)	W/m/K
155	kt 2	Thermal conductivity of layer 2	W/m/K
156	kt 3	Thermal conductivity of layer 3	W/m/K
157	kt 4	Thermal conductivity of layer 4	W/m/K
158	kt 5	Thermal conductivity of layer 5	W/m/K
159	kt 6	Thermal conductivity of layer 6	W/m/K
160	tsoilbm	Average temperature of lower boundary layer	K
161	lecs 1	Water extracted by the root for the layer 1	mm
162	lecs 2	Water extracted by the root for the layer 2	mm
163	lecs 3	Water extracted by the root for the layer 3	mm
164	lecs 4	Water extracted by the root for the layer 4	mm
165	lecs 5	Water extracted by the root for the layer 5	mm
166	lecs 6	Water extracted by the root for the layer 6	mm
167	Storage_rC	Carbon labile concentration in plant	kg C/m <sup>2</sup>
168	Storage_rC_C14	C14 or C13 fraction in Carbon labile concentration in plant	Bq/kg
169	Storage_rrC	Carbon stable concentration in plant	kg C/m <sup>2</sup>
170	Storage_rrC_C14	C14 or C13 fraction in Carbon stable concentration in plant	Bq/kg
171	Storage_rN	Nitrogen labile concentration in plant	kg N/m <sup>2</sup>
172	Storage_rrN	Nitrogen stable concentration in plant	kg N/m <sup>2</sup>